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THE BRITISH JOURNAL OF METALS


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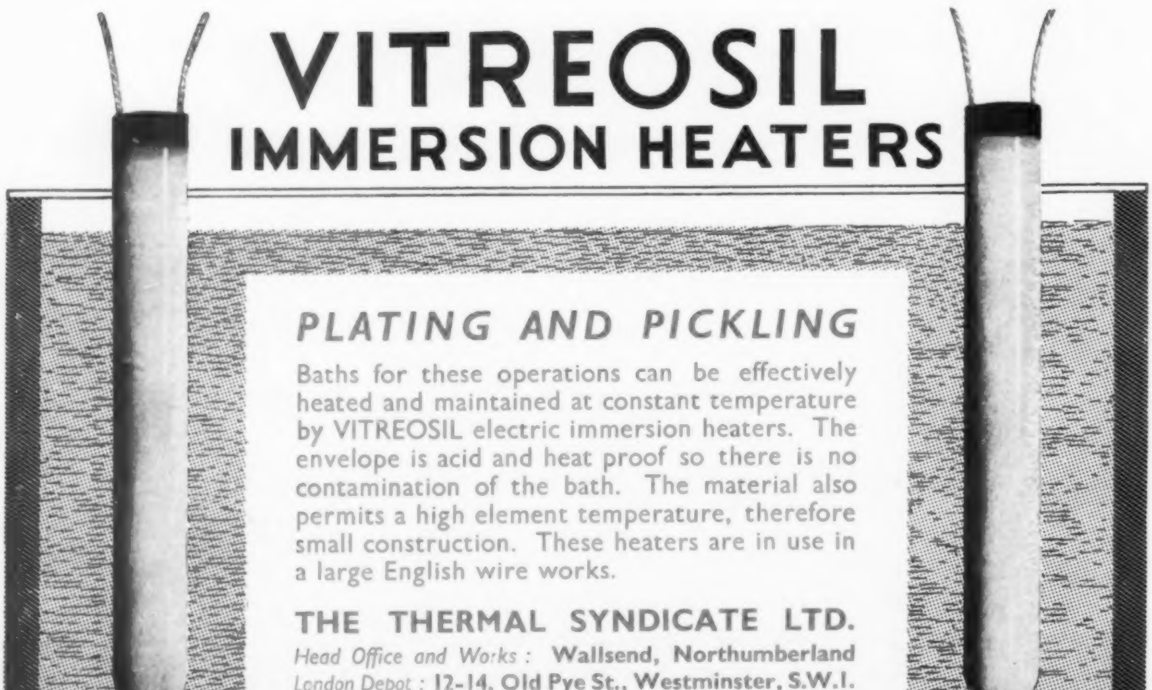
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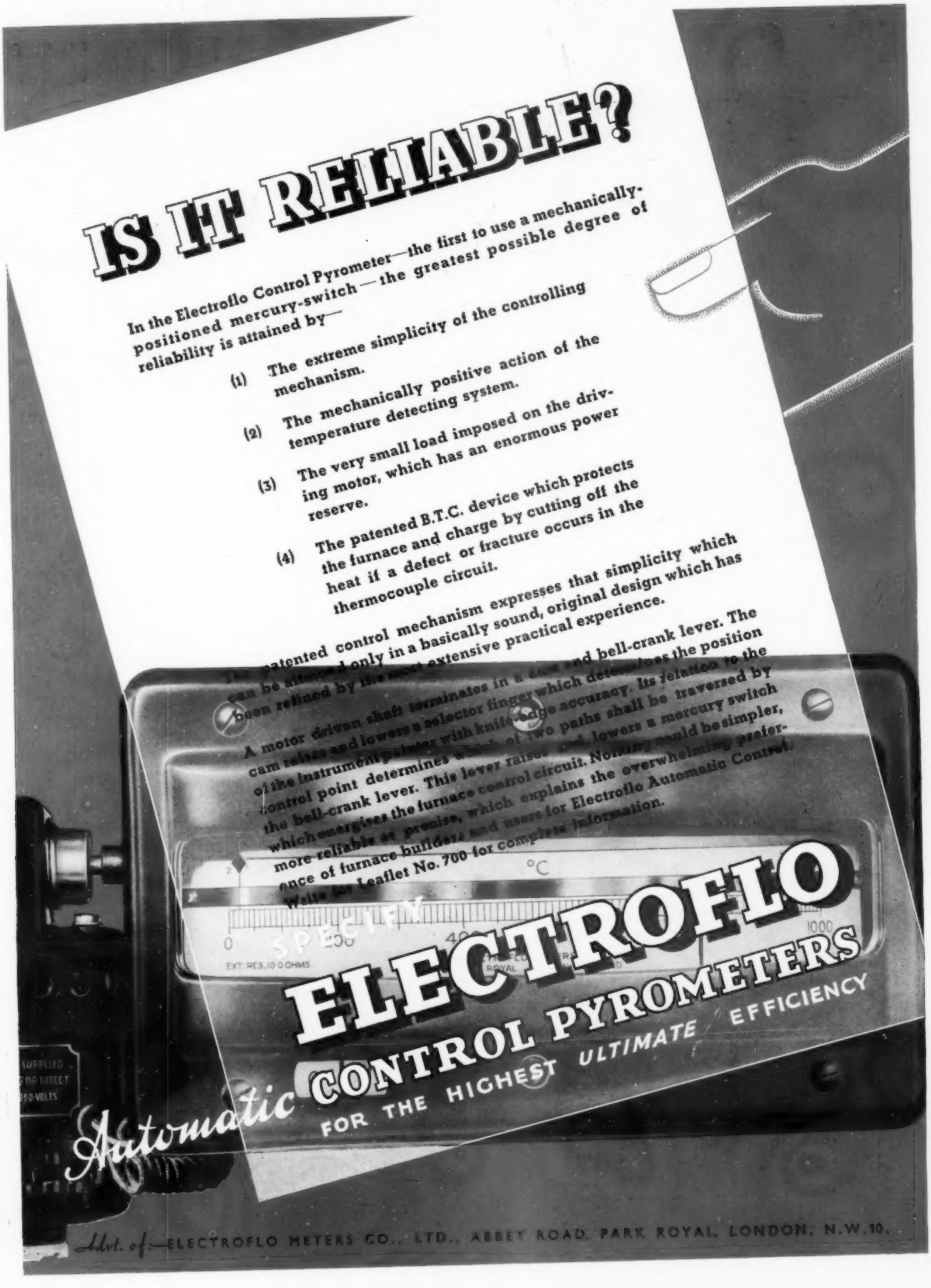
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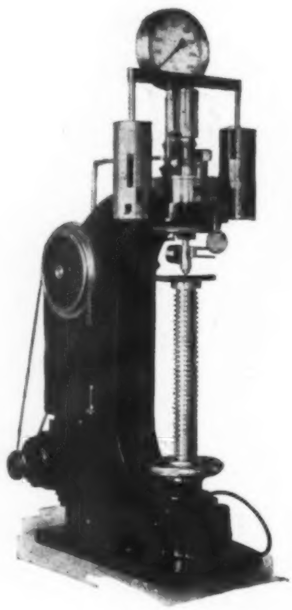

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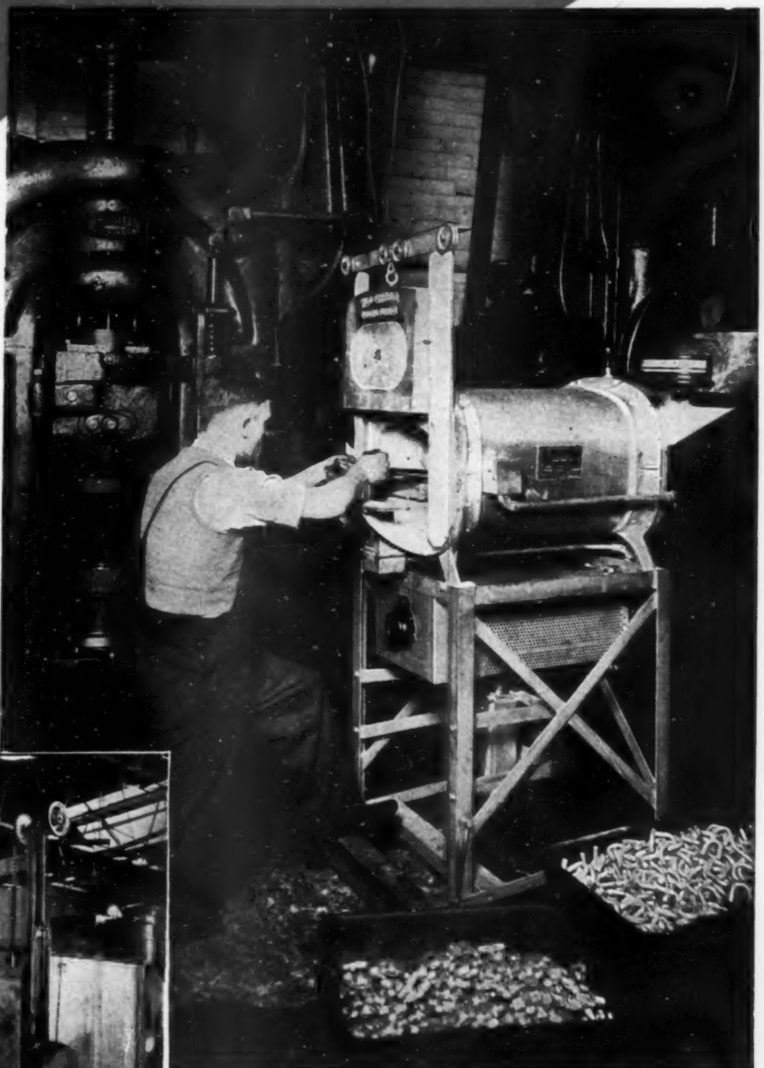

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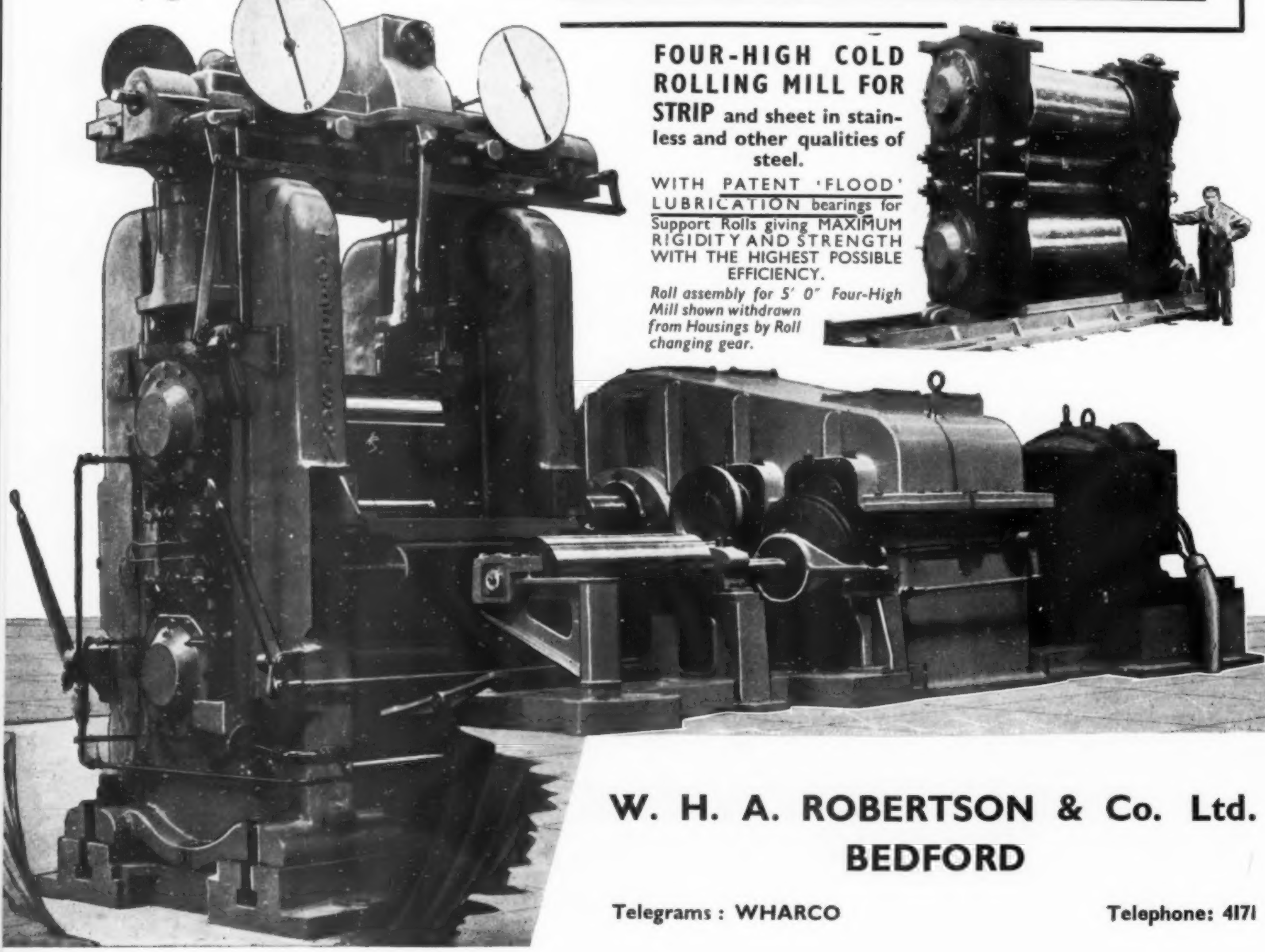

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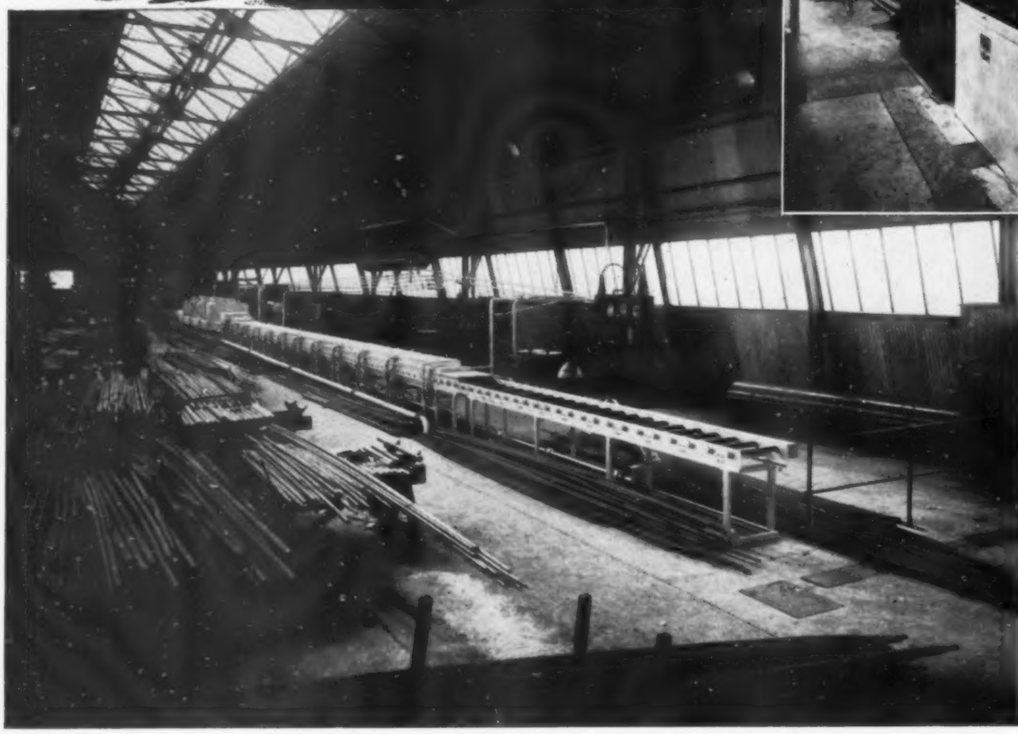
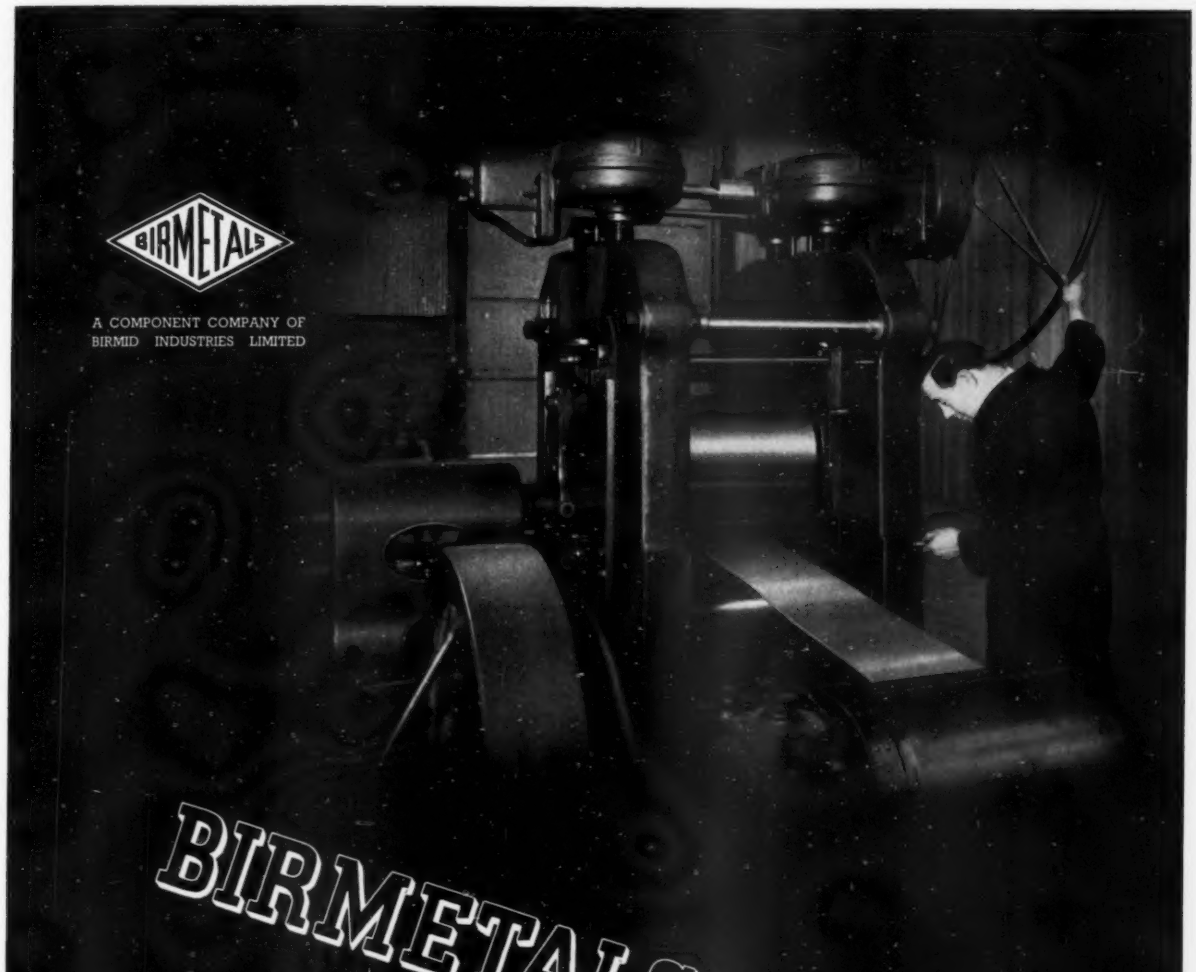


The new furnace recently installed at Jarrow Tube Works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T.G.S.

How GAS and the precious metals aid Industrial Progress

THEY touch industry at a thousand points—gas and the precious metals. And as modern methods replace the out of date they will touch industry at a thousand more.

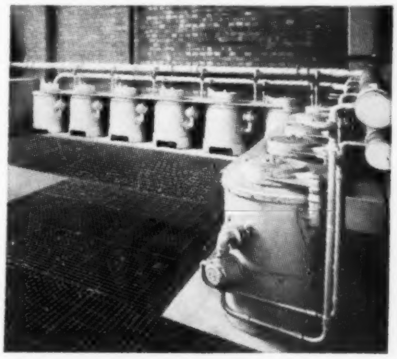
Just as industry relies on gas for a vast number of processes, so there's hardly an industry which Johnson Matthey, the famous precious metals firm, do not supply. Its products are used extensively not only by manufacturing jewellers, but by electroplaters, the electrical, wireless and television industries, the photographic and transport industries, and many others. They make also the containers for radium, and handle the total Canadian output.

Precious metal contacts are the most reliable for all types of relay and switchgear units, for aeroplane magnetos, for road and railway signals, for totalisator equipment. Rhodium plating has improved cinema and searchlight reflectors. Gold fountain pen nibs are tipped with osmiridium, the ideal hard metal to resist corrosion. Gold, too, has its commercial uses—from liquid gold for decorating pottery to gold leaf for signwriting. One firm alone purchased 8,000 ounces of gold last year, enough to make 347 acres of gold leaf.

Johnson Matthey is thus closely in touch with industries, both ancient and modern, and has more than kept pace with industrial developments since the beginning of the eighteenth century when John Johnson first began gold assaying in London. To-day the firm has several works and factories in England for dealing with special or local requirements, and is represented at a score of important world centres. By a steady development of home trade and by overseas expansion, Johnson Matthey has established itself as the foremost precious metal refiner of the world. At the end of the Great War, for instance, the manufacture of rolled gold was almost unknown in England. To-day, however, Johnson Matthey is among the leading firms producing rolled gold, more than capable of supplying all British needs. Every year new uses are found for the precious metals and existing uses are extended. Thus, Johnson Matthey must, as far as is possible, anticipate future requirements of industry.

Such a firm must, of course, pursue a policy that is progressive. It will tolerate nothing out of date or makeshift. Home deliveries are made in Rolls-Royce vans, and overseas orders frequently go by 'plane. Equipment for every process is as efficient as science can produce. Many changes have been made in this firm's works and factories when from time to time a new method has been proved to be better, quicker or cheaper.

The source of heat is one of the problems that gets the closest scrutiny. Technical opinion and exhaustive tests have pointed out gas as the most suitable fuel for a great number of processes. And *vast* quantities of heat are required throughout the year in the making of plate, coinage and precious metal products for scores of industries.



Because of its rapid heat input gas is used extensively in Johnson Matthey's modern melting shop. The air-blast burners fire tangentially to the inside of the refractory lining.

Gas, for instance, is used extensively in the modern melting shops, one of which is shown in the illustration. These crucible furnaces, with their rapid heat input, are ideal for high-temperature work. The air-blast burners fire tangentially to the inside of the cylindrical refractory lining. A refractory collar on the lid fits flush on to the crucible rim, to protect the surface of the melt from the swirling gases. This prevents serious loss through volatilisation and oxidation.

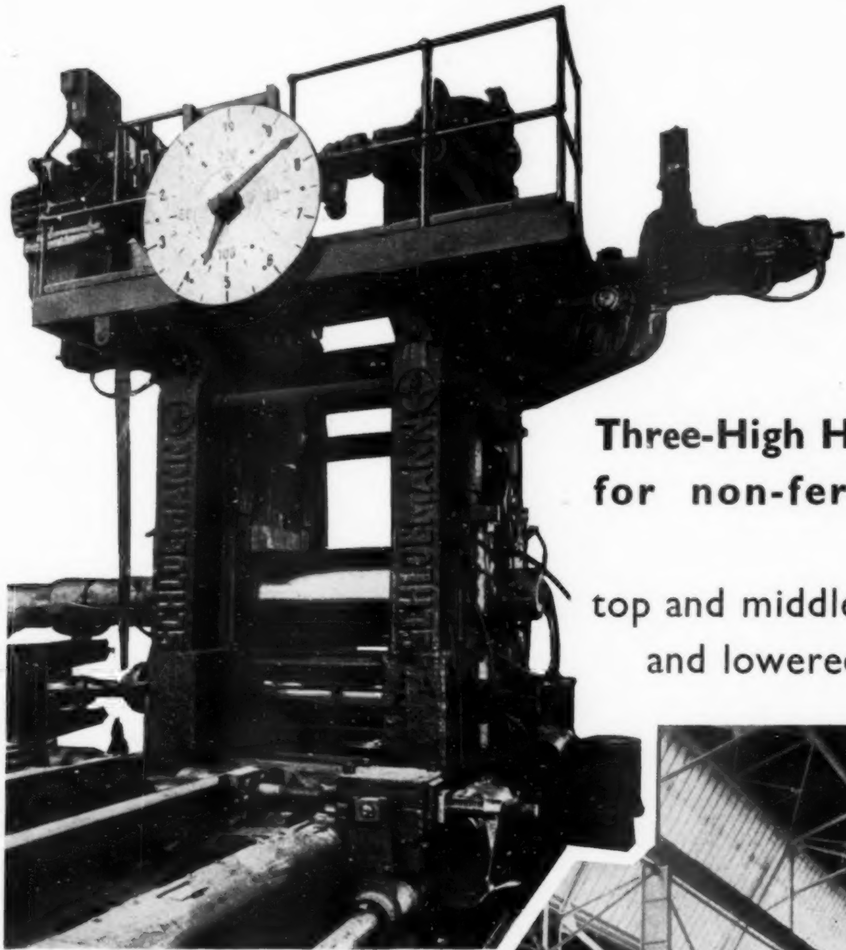
Again, large quantities of gas are consumed in oven and salt-bath furnaces for annealing at various stages of working. Here temperature is accurately controlled by thermostat. Continuous muffle furnaces are used for annealing wire and strip, as these give a more even heating. In the manufacture of rolled-gold products, too, gas-fired furnaces heat up the metals before welding with hydraulic presses. Johnson Matthey also use gas for heat in a wide range of other processes, from soldering to degreasing, and heating the solution for rhodium plating.

A recent development which has extensive industrial applications is gas for low-temperature brazing with Easy-Flo silver solder. This method has considerable advantages. It is approved by the Air Ministry, and is used by many up-to-date engineers.

Another important application of gas is to produce a special atmosphere, where this is required. For instance, Johnson Matthey use such a special atmosphere to prevent surface oxidation of the metals in one of their large sheet annealing furnaces. A mixer and blower are arranged with two inlets calibrated so that the proportions of air and gas may be controlled. The mixture is then burned in a combustion chamber. Products of combustion then go to a condenser, where moisture is removed. The gases then pass through iron oxide to remove sulphur before entering the furnace. Steam had previously been tried for this furnace, but gas has proved itself more economical and satisfactory. Again, gas-fired assay furnaces maintain the necessary highly oxidising atmosphere by means of a pre-heated air purge.

It is only to be expected that gas should be used so extensively by Johnson Matthey, as both gas and the precious metals are so essential to progress in industry.

Expert advice on gas-fired equipment for any industry may be had through the British Commercial Gas Association, Gas Industry House, 1 Grosvenor Place, S.W.1.



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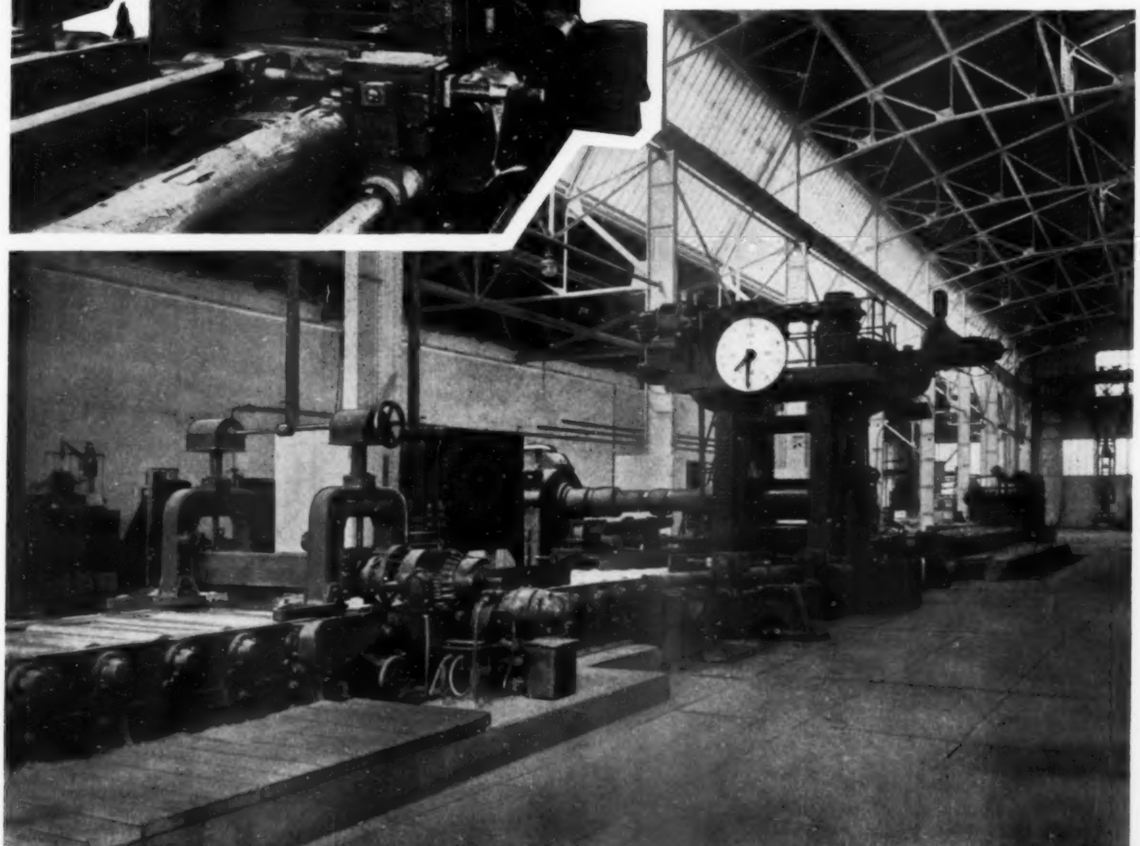

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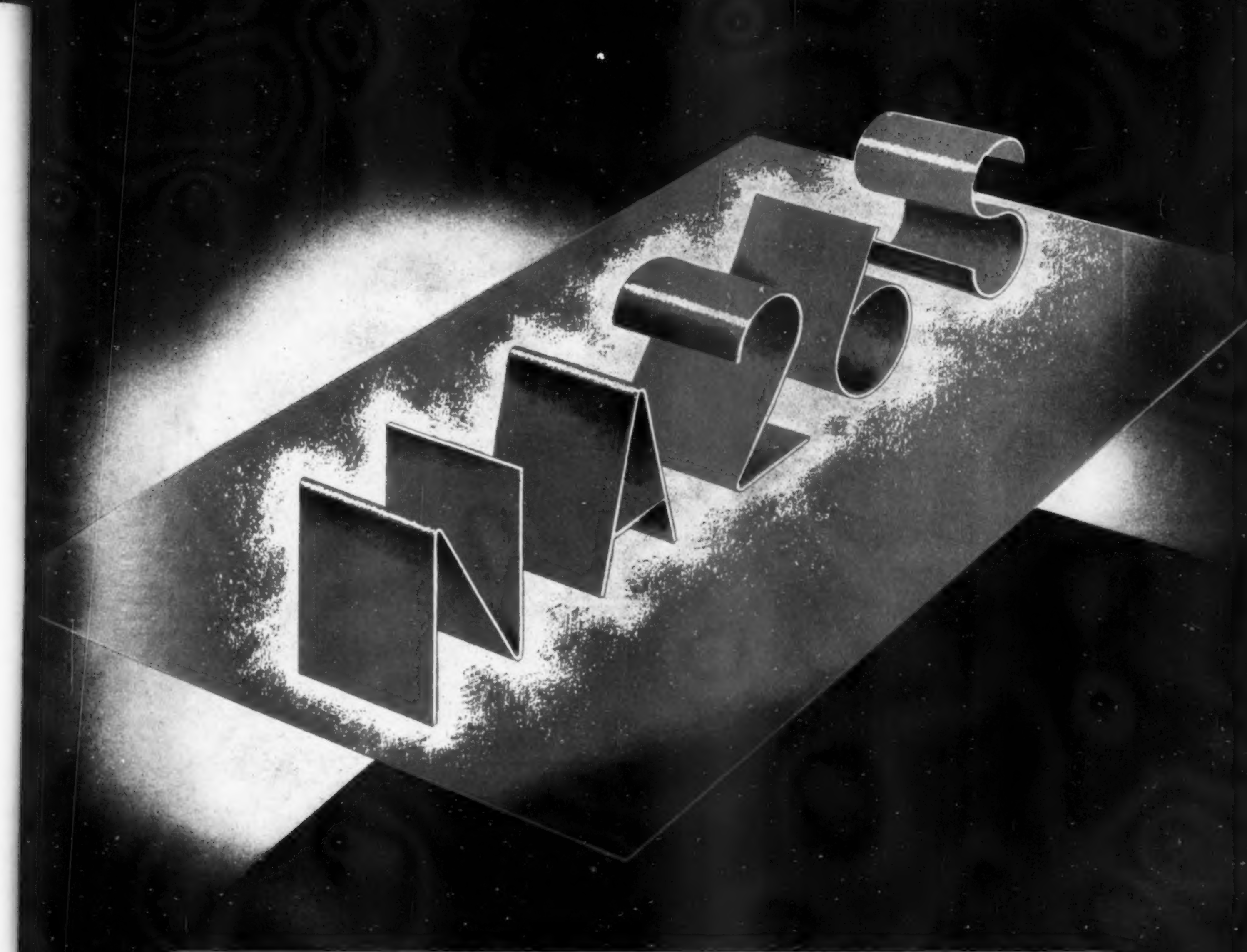
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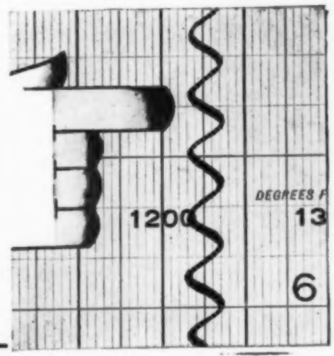

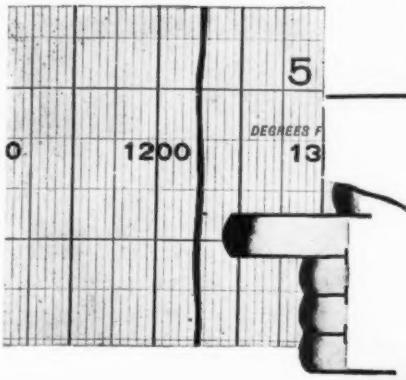

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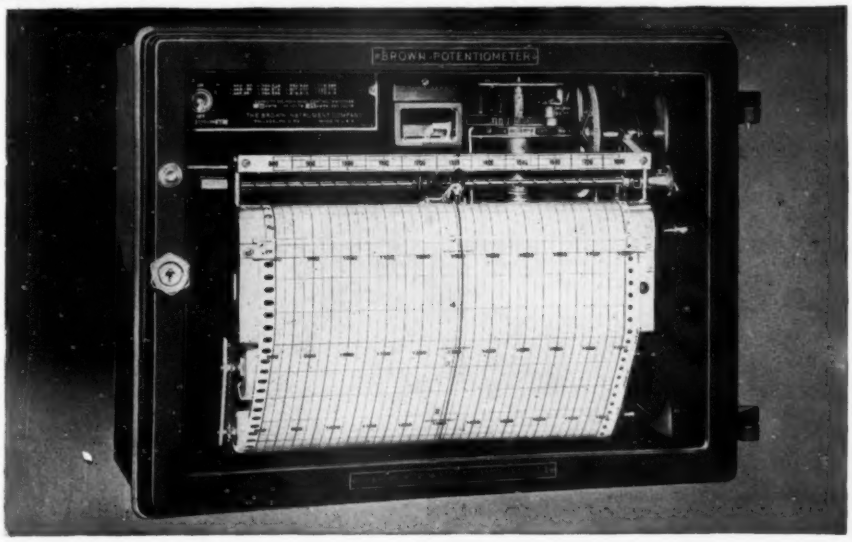

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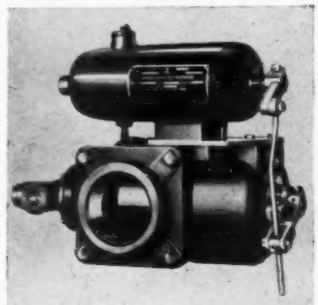

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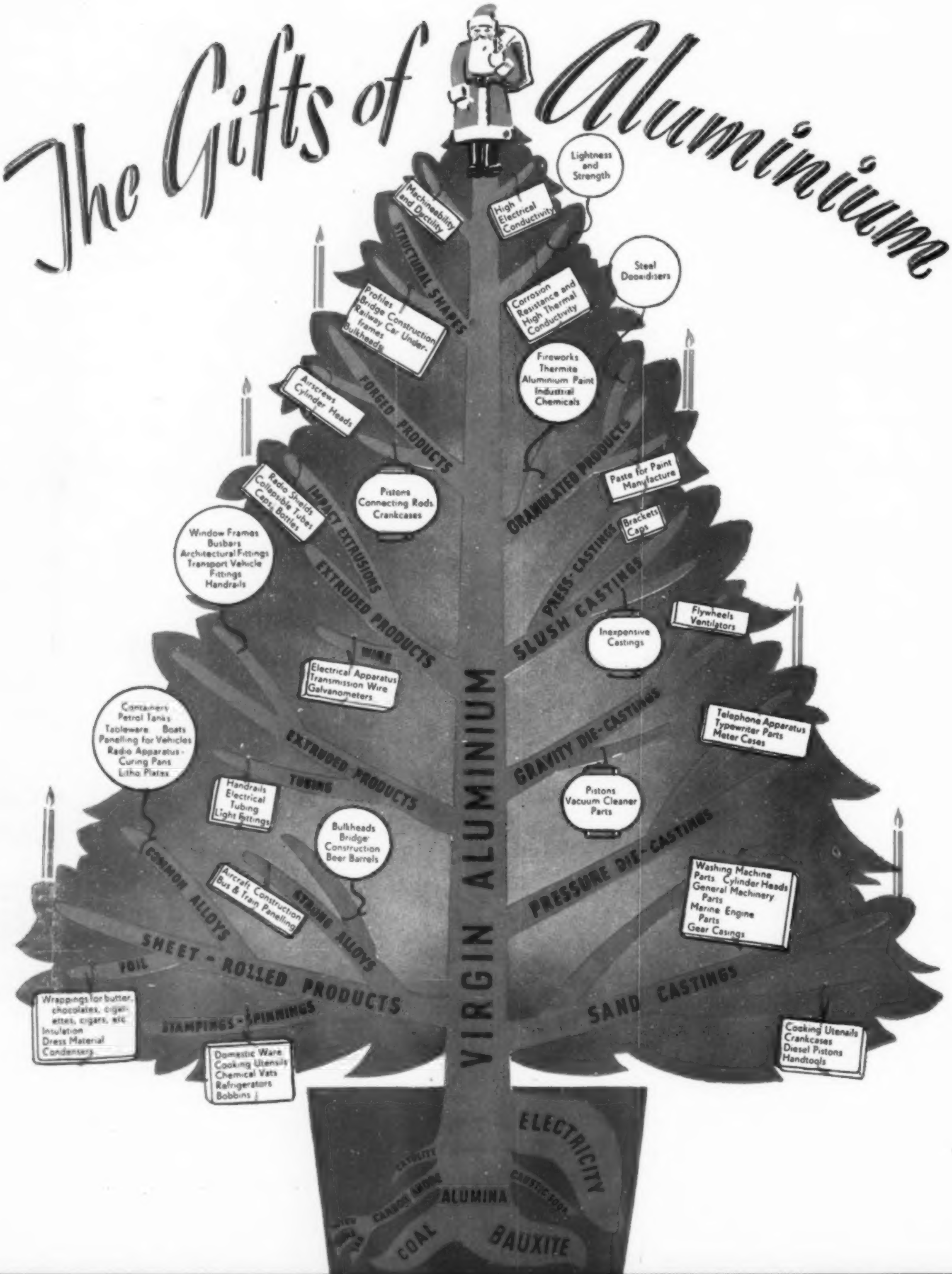
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METALLURGIA

The British Journal of Metals

(Incorporating The Metallurgical Engineer.)

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PRINCIPAL CONTENTS IN THIS ISSUE:

Several articles have been unavoidably held over to the next issue.

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METALLURGIA

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Admiralty Laboratory at Sheffield

A new Admiralty laboratory was opened on December 15, at Sheffield, by Sir William Bragg, O.M., K.B.E., President of the Royal Society, in the presence of the Lord Mayor of Sheffield, the Master Cutler, Vice-Chancellors and Professors of Metallurgy from several Universities, representatives of many Societies, Directors and Chief Metallurgists from several steel companies, and officers representing the three Defence Departments and the Department of Scientific and Industrial Research. Brief information regarding the equipment and purpose of the Laboratory is given.

THE necessity for adequate facilities for inspection to ensure that all materials used in Naval armament work are of a satisfactory standard has long been realised by the Admiralty, and a laboratory to deal with the metallographic and chemical analysis of metals has been in existence in their Inspection Department at Sheffield since 1913. Previous to that the work was carried out in the Admiralty Chemists' Department, Portsmouth.

The wide range of complex alloys developed during recent years, and now being used in armament manufacture, has greatly increased the scope of work in the Laboratory, and the great increase in the volume of work due to rearmament, and to a decision by the Admiralty to make Sheffield the headquarters for metal inspection, have rendered necessary the erection of this new laboratory.

The Laboratory Building

The building, which occupies a site of 5,400 sq. ft., adjoins the Admiralty Gauge Factory in Bold Street, and consists of a two-storied steel and red brick structure, with an intermediate floor on one side, and a basement. The lay-out is on essentially utilitarian lines, and incorporates the latest developments both in construction and equipment. The whole building is served by an air-conditioning system, which provides eight changes of air per hour in the chemical laboratories and four changes in all other rooms. In the former, the air enters through ducts near the ceiling, and leaves through ducts in the fume cupboards, which are connected to a motor-driven extraction fan situated in a chamber at the top of the building. The basement contains the air-conditioning plant, boiler-room, and store for liquid chemicals. A lift connects the latter with the chemical laboratories and with the store for solid chemicals, and apparatus which is situated on the intermediate floor.

On the ground floor a corridor runs the length of the building and separates a block of offices, from a laboratory with an adjoining balance-room which are equipped primarily for the chemical analysis of iron and steel. Lining one side of the corridor are 50 hat and coat lockers of pressed steel

Steel Laboratory

The dimensions of this department are 45 ft. × 33 ft. × 18 ft. high. Windows run the length of the room and extend from bench level to a height of 8 ft. The panes in the lower half consist of Thermolux glass, which provides

Fig. 1.—View of laboratory from Bold Street.

insulation from the heat and glare of the sun. On the opposite side of the laboratory are seven fume cupboards. The walls and the fume cupboards are built of mottled glazed fireclay blocks. The benches have teak tops and are fitted with cupboards, drawers, white glazed sinks, taps for gas, water, and vacuum supply, and plugs for electrically heated hot plates, muffle furnaces, and other apparatus. The flooring material is red acid-resisting asphalt, which is rounded off at the junction with walls, benches, and other fixtures to simplify cleaning. General artificial illumination is provided by eight 200-Watt lamps. There are also bench lights and special daylight lamps for colour comparisons. The fume cupboards are lit from outside by tubular lights having anodised aluminium reflectors.

The balance-room adjoining this department contains, in addition to the usual balance-room equipment, apparatus for the determination of carbon in steel. The latter was designed and constructed by the staff.

Non-ferrous Laboratory

On the first floor is situated a large laboratory with an adjoining balance-room, which are equipped primarily for the chemical analysis of non-ferrous metals and alloys. The dimensions of the laboratory are 60 ft. × 33 ft. × 18 ft. high, and its construction and lay-out are similar

Fig. 2.—Part of heat-treatment laboratory.

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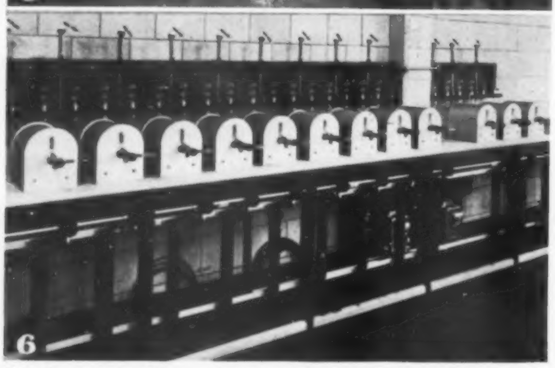

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Fig. 3.—Part of balance room for non-ferrous laboratory.
Fig. 4.—Part of spectrographic and metallographic department.
Fig. 5.—Another section of the spectrographic and metallographic department.
Fig. 6.—Battery of electric furnaces for the determination of carbon in steel.

generally to those of the steel laboratory. It contains, however, several pieces of apparatus specially constructed to suit the work of this department.

The adjoining balance-room, which is very commodious, contains a modern micro-balance, 12 analytical and other balances, and an apparatus for analysis by electro-deposition. The latter consists of 16 stands, each fitted with a friction-driven rotating electrode holder. A single motor-driven shaft supplies the motive power. D.C. current is supplied to the apparatus by two Westinghouse metal rectifiers.

Metallographic and Spectrographic Laboratory

This comprises a room for the preparation of specimens for examination, one for the micro-examination of specimens and the evaluation of spectograms, and a dark room, all situated on the intermediate floor, also a further room on the first floor which is used for the preparation of spark spectrograms, a rather noisy operation which it has been found desirable to separate from other work.

The equipment for metallographic work consists of the usual apparatus for the preparation of specimens, a hydraulic press for mounting specimens in bakelite, Vickers' Projection, Watson, and other microscopes, Phillip's Metallix X-ray apparatus, and electrically heated, drying, and mounting presses. The equipment of the spectrographic section consists of three Hilger, fully automatic large quartz spectrographs with both arc and spark attachments, 3 photo-electric microphotometers, 3 Judd Lewis comparators, a rotating logarithmic W-edge sector, and other accessories.

This section has been responsible for a considerable amount of original research work, particularly on spectrographic methods for the quantitative analysis of steel alloys. Non-ferrous metals and steel are now being analysed as a routine, over 40,000 quantitative determinations having been made during the last twelve months. Further development work is in progress.

Heat-Treatment Laboratory

This section is equipped with a " Birlec " furnace, and a Wild-Barfield high-temperature atmosphere controlled furnace, both complete with panels for automatic temperature control, a temperature recorder, and time switch. There are also smaller electric heat-treatment furnaces, and a fas-fired furnace for melting non-ferrous metals. A high-frequency furnace is shortly to be installed.

The combined staff of the Laboratory, exclusive of clerks and laboratory attendants, is at present 43, but if necessary it could be increased to 60 without inconvenience. Provision has also been made to permit of another storey being added to the building should circumstances demand it, without any dislocation of work.

Canada Leads in Platinum Metals

THE successful development of the copper-nickel mines near Sudbury, Ont., has been largely responsible for increased Canadian production of metals of the platinum group, as the ores of these mines contain a notable amount of platinum metals and are the chief source of the Canadian output. A few ounces are also obtained from the rivers of British Columbia and small quantities are recovered as an impure residue in the refining of gold at Trail, B.C. Since 1934, Canada has been the leader in the world's production.

During the past fourteen years the price of platinum has fallen considerably, decreasing from about six times the price of gold to approximately the same value. This reduction in price, together with research on the possibilities of platinum as an industrial metal has brought about a greater use and increased demand for platinum. Due to its high melting point and specific gravity, its freedom from oxidation at high temperatures, and its comparative immunity to acid, platinum is finding increasing use in the industrial field. In the electrical industry it is used extensively for contact points, power switches, thermostats, resisters for high temperatures, electric control apparatus and clocks, while the chemical industries use platinum for laboratory equipment, for anodes, and as a catalyst in the production of sulphuric, acetic and nitric acids. Rayon firms use platinum for spinnerets, glass manufacturers use it as a dye, and architects employ it as a plating material.

Heat-Treatment Research and Development

Wild-Barfield's New Laboratory

The permissible tolerance in heat-treatment to produce desirable properties in many alloys is frequently very narrow, the operation therefore is of vital importance. To assist in the development of proper technique in various heat-treatment operations, a research and development department has been instituted by Messrs. Wild Barfield Electric Furnaces, Ltd. The purpose of this department and some of the equipment are briefly described.

IT has been said that modern heat-treatment should be considered as an art, since it requires knowledge, skill, and judgment for its proper performance. These, in turn, necessitate at least some knowledge of heat, of metals and alloys, and of the effect of heat on metals and alloys. But, with the increasing demands of the engineer for metals and alloys possessing improved properties, and the development of complex alloys which, with suitable treatment, fulfil these demands, the permissible degree of tolerance in the properties of these alloys has been continuously lowered; it is not surprising, therefore, that at least one furnace manufacturer has taken steps to use the advantages of research to solve problems and to ensure greater accuracy in heat-treatment operations.

It is now more fully recognised that changes brought about by heat-treatment frequently affect the constitution of the metal or alloy by altering the nature, form, size, and even the actual distribution of the components of the metal structure, and since the tolerance in treatment is often narrow, the operation is of vital importance. Modern alloys are frequently so complex that the determination of the most suitable heat-treatment to develop the desired properties requires considerable technical and scientific knowledge.

In order to be in a position to cope with modern heat-treatment requirements, Messrs. Wild Barfield Electric Furnaces, Ltd., have equipped a research and development laboratory in conjunction with their heat-treatment furnace demonstration department. The object of this laboratory is to determine the most suitable heat-treatment operations necessary to produce in client's materials the desired properties. For this purpose samples of materials are submitted to a thorough examination which include metallurgical tests and chemical analyses, and complete information regarding each particular sample will be supplied to clients. Obviously, unless the performance in the shop compares favourably with the standard set in the laboratory the value of the work is lessened; to overcome this, facilities are afforded to reproduce to proper operating conditions in the demonstration department or at clients' works. The company rightly regard heat-treatment as of vital importance in modern industrial development, and are now in a position to give service in the solution of heat-treatment problems, and to develop the most suitable technique for clients' materials or products.

The department is divided into two main sections: the chemical laboratory, where facilities are afforded for making a complete analysis of any sample submitted; and the metallurgical laboratory, where samples are examined and tests made. Brief information regarding the equipment in these sections will be of interest as an indication of the thoroughness in which the department has been promoted.

Metallurgical Laboratory

The metallurgical testing laboratory is adequately equipped, and contains one of the latest types of Vickers' pyramid hardness testing machine, complete with the latest improvements. With this machine the hardness is calculated in terms of the ratio load-impressed area. The measuring microscope is of a special type, capable of measuring to 0·001 mm., and the impression in the specimen is illuminated. Instead of the usual scale or eye-piece micrometer, a specially designed micrometer ocular is provided. The impressions are read to knife edges and readings are taken entirely from a digit counter, mounted on the ocular. This machine is applicable to carburised, nitrided, cyanided work, etc., and is also applicable to very thin sheet.

The latest type of Hounsfield testing equipment is installed for carrying out standard tensile tests on strip, rods, wires, etc.; notch-bar test; slow-bend test; compression tests; and cupping, punch sheet, and Brinell hardness. Graph sheets are attached to a drum on which tests are recorded autographically, so that, for many of the tests, clients can be provided with an actual record of the particular test on his material.

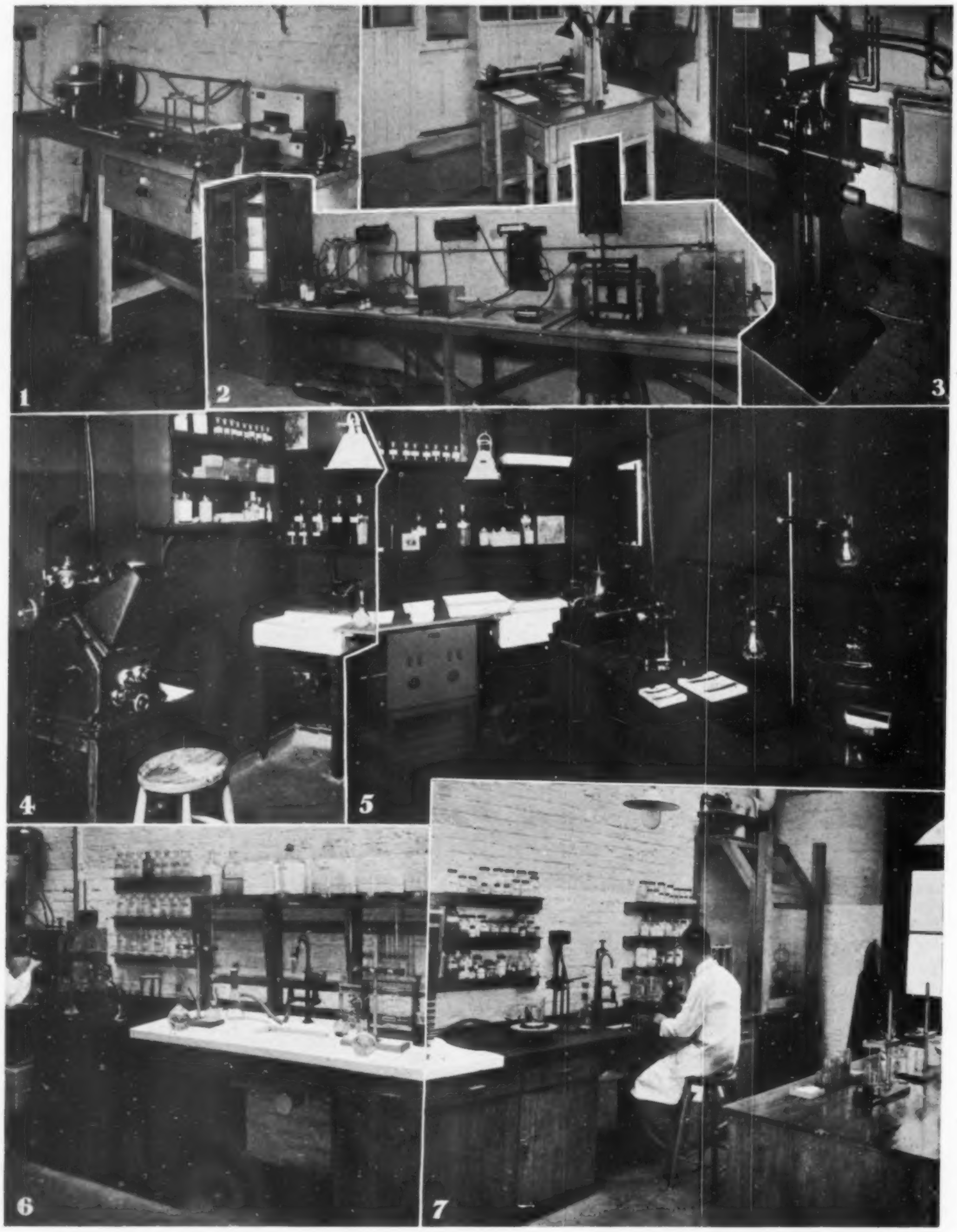
A special bench is arranged for the grinding and polishing of samples for photomicrography, and is equipped with one of the latest types of polishing machines. The equipment comprises all the necessary polishing media for the preparation of both ferrous and non-ferrous samples for microscopical examination. A balance-room is housed in this section, equipped with an Oertling balance, as well as a standard chemical balance.

An optical dark room is set apart for general microscopical work, photomicrography, and qualitative and quantitative spectrographic analysis. It is equipped with all the necessary apparatus for these processes, and comprises a Vickers' projection microscope of the latest type, which is fitted with both types of illuminant: the standard Point-o-lite and the carbon arc. The microscope is complete with the full range of objectives, eye-pieces, etc., required for both micro and macro work, as well as the necessary equipment required when using polarised light. With this equipment a range of magnification from $\times$ 3 to $\times$ 4,000 is available.

A Browning spectroscope is installed which is used not only for the qualitative analysis of alloys, but also for their approximate quantitative analysis. The instrument provides a useful means of determining the components of an unknown alloy and an approximation of the contents of each element present, the information gained, facilitates the investigation of a sample during the time a chemical analysis is made. The metals or alloys to be examined with this instrument are used in the form of rods in the standard type of arc holder, the electrodes being fed by D.C. current at 110 volts.

Chemical Laboratory

This laboratory is equipped with three furnaces of the company's construction: they comprise a solder bolt-heater, for the purpose specified and for general heating purposes; a rectangular type laboratory muffle furnace, which is used for general purpose work for temperatures up to 1,000° C.; and small tubular muffle furnaces, comprising a single tube muffle and a double tube muffle furnace for use in general chemical and metallurgical analysis—e.g., carbon combustion, etc. The muffle furnaces are hand-controlled by means of the ordinary type of resistance and



1. Grinding and polishing equipment. 2. Furnace bench in chemical department. 3. Vickers' pyramid hardness testing machine.

4. Part of optical dark room, showing Vickers' projection microscope. 5. Another section of the dark room, showing the Browning spectroscope.

6 and 7. Two views of the chemical department, showing the general arrangement.

temperature are indicated on a multipoint pyrometer, with dual scale for both base metal and platinum metal thermo-couples. An electrically heated oven is also installed for use in general chemical analysis, and is capable of temperatures up to 200° C.; thermostatic control is incorporated. Other electrical equipment comprises hot plates, and an electrically heated still for the production of distilled water.

The layout of this laboratory is seen in the accompanying illustrations. The analytical bench, furnace bench, and the central benches are well arranged for convenient working. The analytical bench comprises a very modern type, a laboratory fitting with the central portion of the bench allocated to volumetric analysis, it being of construction to take aspirators containing standard solutions, burettes, etc. At the extreme end of this bench is a large fume cupboard, fitted with a stainless steel exhausting fan and special asbestos piping for the removal of noxious fumes. All the necessary chemicals likely to be required in metallurgical and chemical analysis are available in the laboratory, and the equipment is the latest of its type.

The whole department is admirably arranged, and conforms to the best standard for research and development work, and is well equipped to enable the company to carry out thorough investigations for their customers, or in collaboration with customers' own laboratories, technical staffs or advisors. Heat-treatment work is usually carried out in the demonstration department situated in the same premises, and the work can be thoroughly examined before and after heat-treatment. The new department is under the able direction of Dr. F. W. Haywood, and the company is to be congratulated on this development which enables a regulation heat-treatment record and test sheet to be issued to customers, giving fullest particulars concerning the heat-treatment carried out and the results obtained from their own samples.

METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

PROGRESS

WE may acquaint ourselves with the forces that are at work in the world around us, but we can estimate neither their relative strengths nor their persistency under changing circumstances, and it is on these that their ultimate effect must depend. Even if we could calculate the result of these conflicting forces, we should be faced with the problem of the influence of the individual, and it is probable we underestimate this factor especially in those countries where individuality seems to have been relegated to the background. Recent events, however, have shown that, in most countries, the opinions of the average individual are controlled and decisions involving catastrophic consequences to each person appears to rest with a small group of men.

May we take this opportunity of conveying to all readers our Hearty Greetings for the Festive Season and Best Wishes for the coming year

The conflicting forces are the outcome, largely, of the increased complexity of modern international life. International affairs have grown out of all knowledge, both in volume and complexity, and there is reason to fear that the machinery for dealing with the problems has proved inadequate to the task, and in consequence the world is still full of wars and rumours of wars. In many respects, therefore, the problems that have beset mankind throughout the ages are being repeated, and we are left with the impression that what is called progress should rather be termed change. But side by side with these political fluctuations, there is a steady and irresistible advance in that which sets the frame-work of our individual and social existence—the intimate knowledge of the world in which we live and its capabilities, all of which are summed up in the word science.

There is no ebb and flow in development resulting from scientific investigation. Knowledge once gained remains a permanent possession. One age may be more successful than another in adding to the store or in making full use of that which exists, but the totality of the knowledge of the world is ever on the increase. Science is changing the world in which we live by making us more fully acquainted with the properties and potentialities of that which we find there. It has made us see that everything in that world has special potentialities of which we can avail ourselves when the need for their assistance occurs. To-day, science places it in the power of mankind to attain a substantially more rapid rate of progress, if circumstances were such that it could be directed only in the channels likely to uplift mankind, the result of which would be to increase the fruitfulness of human industry which alone will make the world richer.

It is not proposed to discuss here the many fields in which science has contributed to progress, but we can point to the advance of technical knowledge from which can be formed a broad estimate of what has been accomplished in the application of science to industry, in which the metallurgist and engineer is more directly concerned. The accomplishments of the past are a legacy of inestimable worth. The vital importance of such discoveries as those relating to the microscopic study of metals, thermo-electric pyrometry, precipitation hardening, high temperature and creep properties, as well as many others affecting not only the development of new alloys but the improvement of existing ones, must be fully appreciated to facilitate further progress.

During the year that is now almost closed, much work has been done on increasing the purity of base metals, and, in addition, to nickel, zinc, lead, copper, etc., aluminium and magnesium are being produced commercially in a very pure form. Some aspects of progress in the development and production of metals and alloys are discussed elsewhere in this issue, but it will be appreciated that to-day the demands of the engineer are being more readily satisfied, demands which, less than ten years ago, would have been regarded as impossible of accomplishment. In such branches of engineering as aircraft and motor-car production, the tendency is to reduce weight and increase efficiency. This has resulted in the establishment of increasing numbers of standard specifications to ensure a very rigid production control and uniformity of quality of materials, testing facilities having, in consequence, become a routine feature of production control, involving the more general use of proof stress and impact tests. In all phases of metallurgical activity improved products demand a stricter and more accurate control of the basic materials used and in the various technical processes involved in their production.

Progress in ferrous and non-ferrous research is not confined to any one field; the demand to-day for high-grade alloys for every conceivable purpose is very marked, and includes the development of acid and heat-resisting alloys which only a few years ago were still in the embryo stage. The outlook for the future is towards increasing development at a cumulatively rapid rate, and it would appear that firms exploiting the manufacture of ferrous and non-ferrous alloys will survive only acording to their production control, necessitating ever-increasing laboratory technical equipment and the application of the results of fundamental research.

There are no conflicting forces in the progress achieved as a result of the application of science. There are no economic barriers erected against the universal application of the results of scientific discoveries; scientists throughout the world are international figures, and form a brotherhood which could with advantage be copied by politicians. The desire of mankind is for still higher standards of living which increased scientific knowledge will give; on the other hand, however, extravagant expenditure on armaments is responsible for stupendous waste which is preventing mankind achieving its desire. All nations are apparently desirous of peace, but the year has seen opposing forces engaged in destructiou, and no means has as yet been devised to effect peace and limit extravagance in the broadest sense; therefore it is doubtful whether this year will be regarded as outstanding in its contribution to the progress of the world as a whole. But the desire of mankind for a high and still higher standard of life is instinctive, and science offers mankind the power to accomplish this.

Substantial Cuts in Steel Prices

FOLLOWING a meeting of steel interests to consider the new price scale, the British Iron and Steel Federation announced on December 9 that with the concurrence of the Import Duties Advisory Committee, the affiliated associations have reduced prices over a wide range of products, as from January 1, 1939. The reductions in prices range from about 6% to about 8¼%, and they will remain effective for six months.

In fixing the new prices, the Federation emphasise that steelmakers have been confronted with raw material costs which are at present not appreciably lower than they were in the middle of 1937. They have had regard, however, to the economies in production which will follow any expansion in output, and a liberal view has been taken of possible future reductions in raw materials. An optimistic view has also been taken of the trend of demand which the improved November output has probably contributed.

The chief reduction in prices, which are subject to the proviso in all sales and contracts that deliveries after June 30, 1939, will be at the Association prices then ruling, are as follows :—

	Reduction per Ton.
Pig-iron :—	
Basic	7/6
Hæmatite	12/6 (plus reduced extras)
Heavy steel products :—	
Plates (heavy, medium, and chequered)	17/6
Joists and sections	12/6
Rails (heavy)	12/6
Semi-finished steel :—	
Soft basic billets, blooms and slabs for re-rolling :	
Untested	10/–
Tested	15/–
Forging billets, blooms and slabs, basic	12/6
Sheet and tinplate bars	10/–
Rolled and re-rolled products :—	
Merchant bars, sections, hoop and strip, basic :	
Untested	12/–
Tested	18/–
Sheets :—	
Black	£1
Galvanised	£1/5

The reductions generally will ease production costs in the consuming industries, though many users expected more substantial cuts than have been announced, it should be noted, however, that the new prices will be 20 to 25% under the slump level of 1933 with pig iron and coke up by about 37% and imported ore up by about 50%. Cheaper steel is a very important contribution to the lowering of costs in a great number of industries, and should give a fillip to industry generally.

Correspondence

Sir,—May I ask you to correct the impression that may be given by the report of my contribution to the discussion on the paper, "Specific-Heat-Temperature Curves of Commercially Pure Iron and Certain Plain Carbon Steels," by Dr. Sykes and Mr. Evans, given on page 20 of the November issue?

I pointed out that electrical methods as used by Dr. Sykes in the present investigation and by myself 25 years ago were capable of giving true specific heats, whereas the calorimetric method on which Naeser based his conclusions gave mean specific heats over a range of temperatures, and the conclusions he arrived at were not conclusive as regards the existence of "peaks" in the specific heat-temperature curve.

Dr. Sykes and I are in agreement as to the specific heat data.

My subsequent remarks as to the desirability of interchanging samples and varying the method of experiment were directed towards the investigators who had found discontinuities by mechanical tests.—Yours faithfully,

Teddington, EZER GRIFFITHS.

December 3, 1938.

Forthcoming Meetings

IRON AND STEEL INSTITUTE.

Dec. 19. Joint Meeting with the Cleveland Institution of Engineers, in the Cleveland Scientific and Technical Institute, Middlesbrough.

INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Jan. 17. "Practice in Mechanical Testing," by V. E. Green.

LONDON SECTION.

Jan. 12. Selection from Institute papers.

NORTH-EAST COAST SECTION.

Jan. 10. Joint Meeting with Newcastle Branch, Institute of British Foundrymen. "Mechanisation in the Foundry."

SCOTTISH SECTION.

Dec. 20. "Developments in Alloy Sections and Tubes for Marine Engineering," by A. B. Graham. Joint Meeting with the Institute of Engineers and Shipbuilders in Scotland.

Jan. 16. "The Development of Corrosion Resisting Aluminium Alloys," by G. W. Lacey, B.Sc.

STAFFORDSHIRE IRON AND STEEL INSTITUTE.

Jan. 10. "Modern Forging Methods," by F. J. Somers.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Dec. 16. "Electrical Propulsion of Ships," by L. R. Horne, M.Eng.

Jan. 6. "Intercrystalline Cracking in Boiler Plates," by Dr. C. H. Desch, F.R.S.

INSTITUTE OF BRITISH FOUNDRYMEN.

LANCASHIRE BRANCH.

Jan. 7. "Cardinal Points in the Production of Light Castings," by J. A. Reynolds.

BURNLEY SECTION.

Jan. 10. "The Manufacture and Application of Grinding Wheels," by a member of the staff of Universal Grinding Wheel Co., Ltd.

NEWCASTLE-ON-TYNE BRANCH.

Jan. 10. Joint Meeting with Institute of Metals.

SCOTTISH BRANCH.

Jan. 14. "The Relation of Moisture to the Principal Properties of Moulding Sand," by J. Dearden, B.Sc.

FALKIRK SECTION.

Dec. 19. "Alloy Cast Irons," by T. Shanks.

SHEFFIELD BRANCH.

Jan. 5. "Foundry Work in Dentistry," by G. H. Froggatt, L.D.S., M.R.C.S., L.R.C.P.

WALES AND MONMOUTH BRANCH.

Jan. 7. "Why not Green Sand?" by F. Whitehouse.

THE INSTITUTE OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.

Dec. 20. "Developments in Alloy Sections and Tubes for Marine Engineering," by A. B. Graham.

ELECTRO-DEPOSITION OF METALS.

A series of four lectures dealing with various aspects of progress in the electro-deposition of metals will be given by Dr. S. Wernick, M.Sc., at the Northampton Polytechnic, on January 10 and 24, and February 7 and 21, 1939. The chair at the first lecture will be taken by Mr. S. Field, A.R.C.Sc. The inclusive fee for the four lectures is 5s., and in order that readers will appreciate the value of these lectures a brief synopsis of each lecture is given below :—

Jan. 10. "Improvements in Plating Processes."
Brief historical review of industrial developments in the electro-deposition of metals. Most important uses to which electro-deposition is applied. Decorative and protective applications. Nickel and chromium plating; zinc and cadmium plating.

Jan. 24. "Modern Plating Plant."
Development of plating plant, from manual to semi-automatic and fully automatic working. Conditions under which each of these types is best employed.

Feb. 7. "The Anodic Oxidation of Light Metals."
Historical; industrial applications of anodising. The various processes which have been developed in this country and abroad. The dyeing of anodised aluminium. Protection of magnesium and its alloys.

Feb. 21. "Bright Metal Deposits."
The advent of chromium and the platinum metal deposits. Rhodium plating, its development, operation and applications. Bright nickel-plating of brass, steel, and zinc base die-castings.

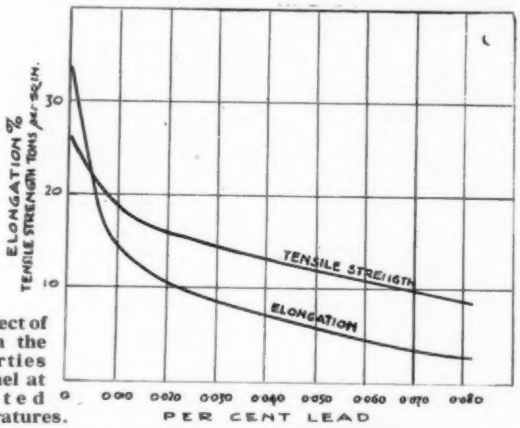
Some Notes on Recent Developments with Nickel Alloys as a Result of Progress in Research

The development of new and improved products in metallurgical fields depends largely upon fundamental research, and in this article recent developments with nickel alloys, as a contribution to progress in engineering, is discussed with particular reference to nickel-copper alloys, heat and corrosion-resisting alloys, nickel-copper steels and nickel cast iron.

Nickel-Copper Alloys

THE well-known series of nickel-copper alloys has for many years been one of the most widely used of the non-ferrous alloys. From 2% of nickel up to the 68% contained in Monel,* a number of compositions exist, each possessing certain useful characteristics. Apart from the long-established 75/25 copper-nickel composition used for coinage and the lower nickel alloys used for locomotive fireboxes and other corrosion-resisting services, one of the most pronounced developments in recent years has been the large-scale production and application of 70/30 cupro-nickel tubes to solve the problem of corrosion in marine and land power station condensers. In connection with these tubes, some interesting information has come to light during 1938 from laboratory research, and on their service behaviour over the last ten years. It is evident now that their resistance to the particularly virulent forms of corrosion from the circulating sea-water, such as impingement attack, is due to their ability to form a highly protective film, which is rapidly formed and is self-healing if in any way damaged. Whilst the tubes originally produced more than 10 years ago have given excellent results, improvements in finish due to advanced methods of manufacture (including the use of tube-reducing machines) and minor adjustments in the composition of the alloy, with particular attention to iron and manganese contents, have resulted in an even better tube being available to-day. The *Queen Elizabeth*, like her sister ship the *Queen Mary* and many other famous vessels, is tubed with 70/30 cupro-nickel. It is interesting also to note trends reported from U.S.A. and elsewhere regarding the use of small percentages of vanadium, chromium, iron, etc., in this type of alloy to modify certain properties.

Turning to Monel itself, as is well known this alloy possesses extremely good mechanical properties at elevated temperatures, and for this reason is extensively employed in many directions. During the past year the effect of impurities was thoroughly investigated, and it has been determined that small amounts of lead seriously affect



The effect of lead on the properties of Monel at elevated temperatures.

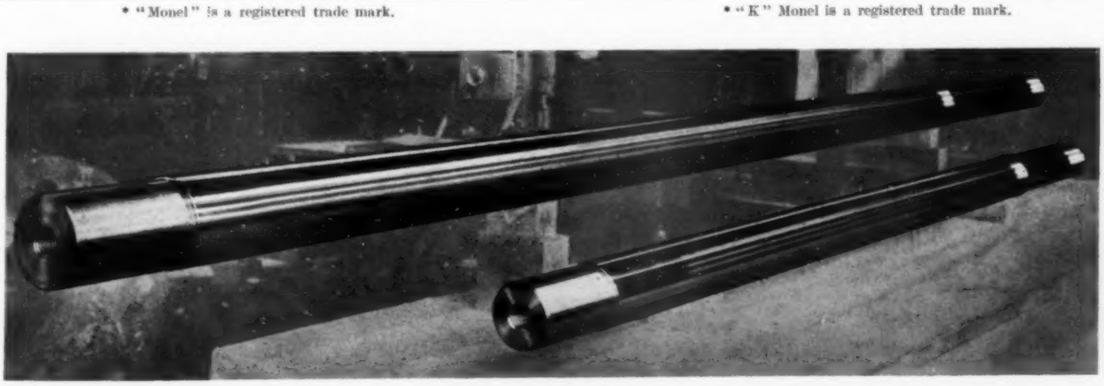
the strength and ductility at steam temperatures, as shown in the attached figure. It will be observed that even the presence of 0·01% lead in Monel reduces the tensile strength and elongation appreciably at 427° C. (800° F.), and if the best results are to be obtained, this element must be absent. This matter warrants serious consideration, particularly so far as the production of castings is concerned, where there may be a tendency for lead contamination to arise. It also indicates the need for the use of raw materials of high quality and purity.

By small additions of aluminium to Monel it has been possible to obtain an alloy which by the application of heat-treatment gives enhanced mechanical properties. Such an alloy known as " K " Monel* possesses after heat-treatment a remarkable combination of mechanical properties for a corrosion-resisting alloy as the figures indicate in the accompanying table.

The fact that " K " Monel is non-magnetic (ordinary Monel is magnetic) has been of great interest to aircraft designers, since it can be used for parts near the compass. It has also found wide application for valve parts and

* "Monel" is a registered trade mark.

* " K " Monel is a registered trade mark.



Two " K " Monel stems, 7 in. diameter × 18 ft. 5 in. long for a large river dam. After heat-treatment the following average properties were obtained from these stems :—

Proportional limit	**40 tons per sq. in.**	**Elongation in 2 in.**	**24.7%**
Yield-point	**49 " "**	**Reduction of area**	**41.6%**
Maximum stress	**69 " "**	**Brinell hardness**	**297**

TYPICAL MECHANICAL PROPERTIES OF "K" MONEL.

Condition.	Yield Point, Tons/Sq. In.	Max. Stress, Tons/Sq. In.	Elongation, % on 2 in.	Brinell Hardness No.	Izod, Ft./Lbs.
Hot-rolled or forged and rapidly cooled	19	39	35	140	100
Hot-rolled or forged and heat-treated	43	60	20	270	70
Cold-drawn and heat-treated	60	72	12	320	50

pump rods, and for other purposes where high strength combined with corrosion resistance are required.

Nickel-plating

For many years the possibility of depositing electrolytically bright deposits in order to save subsequent polishing has quite naturally appealed to all platers. Whilst it has been possible to do this in the case of nickel, it was, until recently, only practicable to obtain very thin deposits, which were also rather brittle and consequently restricted the use. Latterly, however, there have appeared as a result of considerable research new types of bright nickel-plating solutions from which relatively thick deposits of nickel can be obtained, and which do not suffer from the drawbacks of the earlier solutions. These new type bright nickel solutions are now being increasingly employed in a wide variety of industries.

Nickel Bronze

Developments in connection with the nickel-copper-tin alloys are progressing steadily. Bronzes containing 5·0 to 6·0% nickel, 5·0 to 10·0% tin, exhibit higher resistance to cavitation erosion than phosphor bronze and gunmetal. Accordingly, they are being employed in the "as-cast" state for pump impellers, etc., both in the United Kingdom and abroad. In addition, the use of nickel bronze gives a much better surface finish on the vanes of the impeller, and this reduces fettling cost and increases the efficiency of the pump considerably. Bronzes within the range of composition given above are also susceptible to age-hardening when greatly improved mechanical properties are obtained. In the past it has been understood that in order to effect satisfactory age-hardening it was necessary to employ a homogeneising treatment at 760° C., followed by quenching and reheating to 290° C. The initial high temperature homogeneising treatment is open to several practical objections, and a distinct advance has been made by the recent disclosure that nickel-bronze castings can be aged, if necessary, direct from the mould. For example, castings containing 5% nickel, 5% tin, 2% zinc, balance copper, heated direct from the sand at 290° C., give an excellent range of mechanical properties as shown below :—

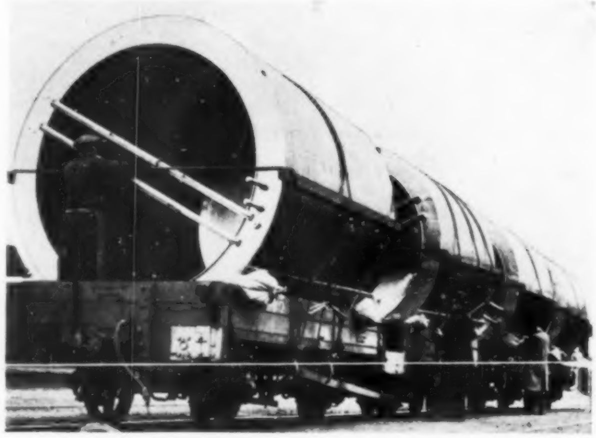
Max. stress, tons/sq. in.	27·0 to 32·0
Yield-point, tons/sq. in.	18·0 to 27·0
Elongation, %	16·0 to 5·0
Brinell hardness number	120 to 170

The high ratio of yield-point to maximum strength should be particularly noted.

Bronzes containing 30 to 50% nickel, 5 to 12% tin, have proved suitable for corrosion-resisting bearings operating with stainless steel and Monel shafts.

Nickel-aluminium Alloys

The use of the nickel-aluminium alloys, such as "Y" alloy, the "RR" series of alloys, Birmasil Special, is already well known for structural purposes at both room and elevated temperatures. Recently, however, as the result of a considerable amount of experimental work, a new nickel-containing aluminium alloy, known as "A.C. 9," has been developed for bearings, especially those which have to operate under arduous conditions of high speed and load, such as on motor vehicles, where the service may be too severe for white metals.



By courtesy of Firth Vickers Stainless Steels, Ltd.

Cream storage tanks made of austenitic nickel-chromium corrosion-resisting steel.

Heat-resisting Alloys

Improvements continue to be made in the nickel-chromium heat-resisting alloys. The 80/20 composition, for so long standard for electrical resistance heating wires and tapes, is now produced with a life on test several times that of the material produced a few years ago. The 80/14/6 nickel-chromium-iron composition, known as "Inconel,"* is being found of great value for many heat-resisting applications, notably for aeroplane engine exhaust manifolds and tubular sheaths for electric resistance heaters used on domestic cookers. It is not generally realised that besides being resistant to the effects of heat, the group as a whole also possesses a corrosion-resistance of a high order, in many cases comparable with that of the austenitic stainless steels.

Inconel has proved to be particularly suitable for service in the dairy and food industries in view of its resistance to the corrosive effects of milk, fruit juices, wines, etc., and whilst fabricated sections have in the past been readily available, the production of castings has been slow, due to insufficient knowledge of foundry technique. Practical research has now been completed in connection with this matter, and simple methods have been evolved for the efficient production of castings by any reasonably equipped foundry.

Nickel-containing Permanent Magnets

One of the more important metallurgical developments of recent times is that of the nickel-containing permanent magnets. Up to a few years ago, the various grades of cobalt steel were unquestionably the best permanent magnet alloys on the market. In recent times, however considerable research has been given to the precipitation hardening of nickel-aluminium steels. Amongst other properties, these steels possess remarkable magnetic retentivity and various grades of nickel-aluminium or nickel-aluminium-cobalt steels offer to-day the highest magnetic quality now commercially available.

The high magnetic energy available in these alloys has resulted in many striking developments in the field of electrical engineering; just to mention one, the Hudd system of safety signalling on the railways, which has been tried out successfully in service, depends on the use of large magnets of nickel-aluminium cobalt steel which exert such magnetic energy that they will operate controls on a train passing at the highest speeds.

Corrosion-resisting Steels

Recent work in connection with the corrosion-resisting austenitic steels has perhaps been more concerned with manufacture and manipulation—i.e., melting, casting,

* "Inconel" is a registered trade mark.

rolling, forging procedure, etc., rather than with investigations directed towards the development of new compositions. The types of steel which are already well known, for example, the 18% chromium, 8% nickel composition, to which small percentages of other elements may be added to meet particular requirements, have not undergone any substantial modification. Such changes as have occurred have been in the direction of overcoming difficulties in manufacture and fabrication, and this has resulted in making it possible to produce articles in the cast, rolled and wrought forms which hitherto were deemed impossible.

With regard to applications, the domestic and architectural fields and chemical and allied industries account for the major consumption of these steels, but much attention has been devoted to their utilisation in other industries. The ease with which the material may be fabricated and its availability in almost all forms have resulted in innumerable new applications where the service conditions demand a high strength-weight ratio combined with a high degree of corrosion resistance. In railway equipment, for instance, stainless steel is being increasingly applied, especially for coach construction. In power development, oil-refining, aircraft engineering, and the process industries, stainless steels are now regarded as standard for components and equipment which are called upon to fulfil a wide variety of functions.

Alloy Steel Tools

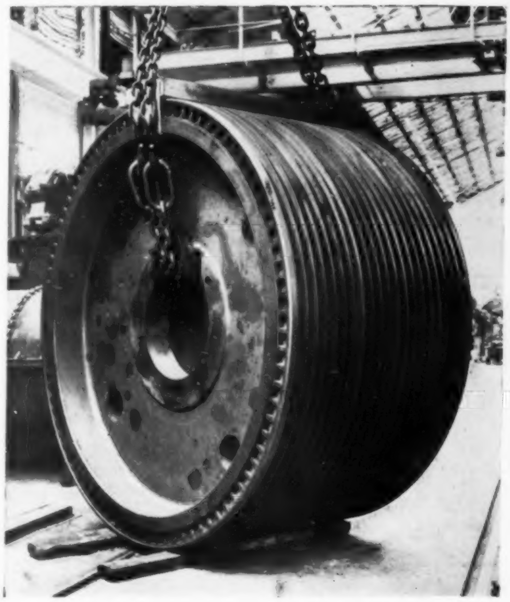
Considerable progress has been made in the adoption of nickel-containing steels for engineers' tools, such as wrenches, spanners, screwdrivers, etc., the steels favoured for these applications being the nickel-chromium and nickel-molybdenum types. A large number of such tools in use have long ceased to be what may be termed "hand-tools," and they are now power-operated, for example, in automobile assembly lines. Continued use necessitates adequate resistance to impact and fatigue which are probably the essential requirements in order to ensure long life.

Nickel-copper Steels

An interesting development which has received a good deal of prominence lately is the introduction of nickel in the copper-containing steels for use in the normalised or as-rolled condition. There are a considerable number of types having varying nickel and copper contents which are made in two carbon ranges—one being about 0·1% or below, and the other 0·15–0·25%. The nickel and copper contents range up to 2·0% and 1·5% respectively. The combined addition of nickel and copper to steel results in increased tensile strength compared with carbon steels together with adequate toughness. The outstanding feature, however, of these steels is their relatively high yield point and yield ratio. Yield ratios of some 70% are obtainable in the normalised condition. The tensile strength range varies, depending on the carbon content, but it may be said to be between 28–42 tons per sq. in.

Advantage is taken of the mechanical properties, particularly the yield point, in utilising these steels in place of carbon steel for applications where reduction of weight can be effected. Possibly in this connection the most widely used field is in applications, such as railway rolling stock, road transport, excavating machines, and other engineering products, where an obvious direct gain is obtained in reduced weight, so contributing to savings in running costs.

It sometimes happens that when steels of improved mechanical properties are developed difficulties arise in fabrication, and these may be such that advantages in mechanical characteristics may be quite offset by workshop difficulties. Continued research work with these nickel-copper steels has led to means being found to overcome initial manufacturing and fabricating difficulties. In fact, these steels, as now commercially available, possess features of value to engineers in that they may be readily cold-



By courtesy of J. and E. Hall, Ltd.

5-ton pulley wheel casting in high-duty nickel cast iron (tensile strength 20 tons per sq. in.).

pressed, and, with the low carbon content steels particularly, welding can be carried out without difficulty. It is due to the combination of these characteristics—that is, good mechanical properties and ease of fabrication—that it is possible to redesign entirely structures of reduced weight and with an adequate factor of safety.

A further characteristic possessed by these steels is their superior resistance to corrosion. It has long been known that the inclusion of copper considerably improves the resistance to corrosion of carbon steels, and the addition of nickel enhances the properties in this direction. The presence of nickel also helps in overcoming certain difficulties which are experienced in the hot-rolling of copper-containing steels.

While these steels cannot be compared with the austenitic nickel-chromium steels in their resistance to corrosion, they do afford a means—and a cheap one—of securing more adequate resistance to corrosion, compared with carbon steel.

Nickel Cast Iron

Continuous progress has been made with the improvement of the mechanical properties of cast irons. This can be attributed in large part to a better understanding of the principles of cast-iron metallurgy and to better foundry technique. The use of alloys, however, to give further improvement in properties and a greater measure of control is now well established.

Some results of the progress which has been made in cast iron in recent years can be obtained by comparing the original B.S.I. Specification No. 321, which was drawn up in 1928, with the specification for high-duty cast irons which was issued in 1938. The maximum strength on the 1·2 in. diameter bar demanded by the earlier specification was 11 tons per sq. in., whereas the new specification covers three grades of castings, in which the strength on the same size of bar is respectively 14, 17, and 20 tons per sq. in. In the last grade the strength on the 0·875 in. bar is 22 tons per sq. in. That such figures are now possible depends on a combination of the features mentioned above. In nearly all cases the higher strengths are achieved by a measure of alloying with nickel, with or without other elements. These high-duty cast irons have come to stay, and are already replacing parts made in cast steel on the one hand or allowing substantial increases in stress or reductions in section on the other.

Striking developments have also been made in recent times in the grades of cast iron possessing special properties developed as a result of higher alloy additions ; a typical example is "Ni-Hard" which represents the hardest commercial iron now available and which is used increasingly for conditions where severe abrasion is encountered. Applications include crusher and grinder parts, pumps, wear plates and screens used, for example, in the coal and coke and mineral industries.

The corrosion-resisting austenitic cast irons, such as "Ni-Resist" and "Nicrosilal," are becoming of increasing importance in the chemical and allied industries ; space does not permit giving details of these applications, but it is sufficient to say that these developments are the result of recent research through which the scope of usefulness of cast iron has been widely extended.

A particularly interesting development is that of the high nickel cast irons with controlled expansion characteristics, as in the case of the high nickel steels. Modification of the nickel content allows exceptionally high or exceptionally low expansion coefficients to be obtained.

Fatigue in Steels

Present knowledge regarding some aspects of the behaviour of steel under repeated stress is briefly reviewed.

THE history of fatigue investigation dates back to the experiments of Hodgkinson in this country 100 years ago, and includes the work of Fairbairn in 1864, and the 12 years' experimental work undertaken by Wöhler in connection with repeated torsion, bending and direct stress.

In discussing fatigue and corrosion fatigue of steels, Mr. B. B. Westcott* reviews present knowledge regarding some aspects of the behaviour of steel under repeated stresses ; the fatigue limit or endurance limit of steel being the measure of its ability to resist repeated stresses.

One of the findings given is that in a general manner the ratio of endurance limit to tensile strength or the endurance ratio, as it is commonly called, is greater for low and medium carbon steels heat-treated to give maximum ductility than for higher carbon steels heat-treated to give high strengths, but in spite of this generality there is no correlation apparent between endurance limit and ductility. According to the dynamic theory of suddenly applied loads, the maximum instantaneous stress produced is twice that which would be imposed if the same load were applied gradually ; and the minimum or dead-load stress plus twice the live-load stress equals the tensile strength. The author points out that metallographic studies of steel under repeated stresses have shown that rupture is always preceded by the phenomenon of slip, and that fatigue failure is inevitably associated with failure of elasticity by that process of slip, the former being the sequel to the latter.

The nature of slip is admittedly obscure, but the theory of the mechanics of failure by failure can logically be imagined, several interesting premises are made by Mr. Westcott, thus, for instance, he states X-ray analysis has shown that slip is not merely relative movement between adjacent parts of the crystal, but that the structure becomes fragmented into component parts of differing orientation. This action, as is well known, is accompanied by strain hardening, but there is no certainty that strain hardening is a direct consequence of fragmentation. Continued application of stress causes the slip and strain hardening to proceed, not uniformly, but locally both with respect to individual grains and with respect to sections within the grains at the junctions of the crystallites formed by fragmentation or crystal break-up. The state of strain upon atomic bonds at these boundaries is intense, and the limiting value of some is ultimately exceeded as the process of cold working by repeated stressing continues so that rupture is produced in the atomic lattice structure. When the stress exceeds the fatigue limit the rupture of atomic bonds becomes a cumulative effect, with the result that the discontinuities of structure develop through the stage of submicroscopic cracks into that of visible cracks which spread, under continued stressing, in the well-known progressive manner of fatigue failure. According to this theory, a fatigue crack has its inception within a grain and is propagated in an intracrystalline manner rather than in an intercrystalline manner. An interesting side light of this basic work being carried out at the National Physical Laboratory is Gough's suggestion that crystallites make up the grain boundaries in metal and that change of orientation between grains is effected by a number of very small crystallites of slightly differing orientation, the structure of each being apreciably free from lattice distortion but having strained or ruptured atomic bonds at the junctions. This conception, it appears, is more in harmony with the known facts of the crystalline nature of metals than the older amorphous theory of Rosenhain. The discussion of the important role of slip-in failure by fatigue must be terminated prematurely by the observations that while slip is most readily developed at high stresses, slip bands have also been observed after a large number of cycles of stresses considerably below the endurance limit. Therefore, visible slip does not necessarily connote impending fatigue failure. Conversely, an absence of visible slip is not a positive indication of freedom from damage.

Experiments in connection with corrosion fatigue show that six generalisations are possible ; that there is no relation between corrosion endurance limit and tensile strength ; that there is no definite effect attributable to the carbon content in plain carbon steels ; that medium alloy steels have slightly higher corrosion fatigue limits than plain carbon steels, the benefit, however, not being regarded as commensurate with the greater cost ; that internal stress resulting from heat-treatment has an adverse effect on the corrosion fatigue limits of plain carbon and medium alloy steels ; that, as would be expected, corrosion-resisting steels have higher corrosion fatigue limits than carbon or medium alloy steels ; and that chromium is more effective than nickel for increasing the corrosion fatigue limits of corrosion-resisting steels.

Some most interesting data was established as the results of corrosion-fatigue tests made in the absence of air, tending to show that damage from corrosion fatigue is less in salt water in the absence of air than in fresh water in the presence of air ; that some of the medium alloy steels suffer less damage through corrosion fatigue than carbon steels, low carbon steels, however, are damaged less than steels with medium or high carbon contents ; and that heat-treated steels suffer greater damage than when in the normalised, hot-rolled or annealed conditions. In the presence of hydrogen sulphide, nickel was found of the greater advantage for increasing corrosion-fatigue resistance, but chromium was found more effective for this purpose if hydrogen sulphide were absent.

It was established that the damage to steel by corrosion fatigue is largely dependent upon the rate of corrosion, and that the effect of repeated stresses upon the rate of corrosion is of minor significance.

* *Mech. Eng.* 6. 11. 813/22.

Copper and Copper Alloys

A Survey of Technical Progress during 1938

By H. J. Miller, M.Sc.

Recent work on copper and its alloys is reviewed, and attention directed to developments in the production and properties of cast copper; properties of wrought copper; properties of brass; properties of tin bronzes; copper-lead bearings; copper-chromium alloys; alloys for electrode and contact purposes, including other electrical alloys; copper silicon alloys and other alloy groups; resistance to oxidation and corrosion; some applications of copper; and joining practice, including soldering, bronzing, and welding.

A SURVEY of metallurgical developments pertaining to copper and copper alloys is a task of considerable difficulty principally because of the large volume of technical information published during any one year and the necessity for care in the selection of references. This review mentions a total of 66 of the more important papers and patents which have appeared during the past twelve months, these having been selected mainly on account of their bearing on industrial practice.

Production and Properties of Cast Copper

Apart from modifications in conventional refinery practice, as, for instance, that described by Benard,[1] in refining molten blister copper at Ontario, the last year has witnessed several interesting manufacturing developments, although these cannot strictly be said to fall within the scope of one year's progress.

It might broadly be accepted that over the last few years the greatest amount of effort has been directed towards the production of copper free from or containing only small amounts of oxygen and also to its casting in vertical moulds. These changes have been reflected in appreciable improvements in the quality and properties of the finished products, particularly as regards ductility, and the advantages have also been stressed in the case of a type of oxygen-free high-conductivity copper which has recently been placed on the British market.[2]

Amongst British patents granted during 1938 are two which deal directly with the production of oxygen-free copper. In a patent of the American Metal Co.,[3] it is proposed to make oxygen-free copper in a modified type of furnace, the metal being charged by a vertical tubular extension on one side of the furnace where reducing conditions prevail, and overflowing from a similar tubular extension on the other side; this section forms part of an evacuated chamber containing the moulds. The other patent[4] is concerned with the heating of cathodes in an electric radiating furnace under such conditions that the hydrogen occluded in the cathodes is freely liberated; the degassed cathodes are afterwards melted by raising the temperature of the furnace and the ultimate cast shapes are claimed to be entirely free from hydrogen unsoundness.

Direct and continuous casting methods have been under development for many years, and much experimental work has been expended on the casting of copper and of other metals and alloys. It is perhaps true to say that the year 1938 has witnessed the fruition and commercial success of certain of these efforts, while in other cases certain processes have been abandoned. The terms "direct casting" and "continuous casting" are applied to the production of semi-fabricated products and of cast billets and ingots respectively. While continuous casting processes can now be regarded as being more or less proved, direct casting cannot yet be considered as fully developed.

Of direct casting methods, the Hazelett and Eldred processes for producing strip and rod respectively are the best known. The Hazelett process, while having now proved unsuitable for certain types of brass, has been applied with a certain measure of success to the production of oxygen-free copper strip. The Eldred process has apparently not yet proved entirely suitable for copper.

The continuous casting of copper billets has been undertaken on a large scale at one American refinery which is now marketing phosphorus deoxidised copper billets of 3 in. diameter cast by a method which has not yet been publicy described. At another American works the German Junghans process, which incorporates a copper water-cooled mould which has a reciprocal motion so as to prevent adhesion to the walls as the molten metal becomes solidified, is understood to have been successfully applied to the casting of much larger billets.

A further very promising method of producing billets does not involve casting at all, although it is included in this section for convenience. This process involves the production of brittle cathodes which are roughly broken up and sintered in a reducing atmosphere into a billet shape; this is then extruded into a billet suitable for later piercing and drawing. The method is restricted to electrolytic quality copper only and the product is free from oxygen, which may in this case prove to be a detrimental feature, since for some purposes at least other varieties of copper are preferable.

Corson[5] has made a detailed examination of certain mechanical properties and of the density at various positions throughout the section of horizontally cast wire bars of tough pitch copper and of vertically cast ingots of deoxidised and oxygen-free copper. This work has emphasised the greater soundness and strength of cast oxygen-free copper.

Lorig, Dahle, and Roberts[6] have provided some extensive data on the mechanical properties at elevated temperatures of oxygen-free and tough pitch high-conductivity copper in the cast states, and this data also shows the advantages of oxygen-free copper. In addition, Goetzel[7] has described certain tests on cast oxygen-free copper.

The influence of a wide range of added elements on the macrostructure of cast copper has been studied by Northcott,[8] who has attempted to correlate the crystal growth restriction factor with the valency and atomic structure of the elements added.

Properties of Wrought Copper

The comparison of the properties at elevated temperatures of tough pitch and oxygen-free copper undertaken by Lorig, Dahle, and Roberts,[6] included hot-rolled products in addition to cast materials; it was found that the ductility of hot-rolled oxygen-free copper was somewhat better at all temperatures up to about 600° C. Goetzel[7] also dealt with wrought oxygen-free high-conductivity copper, and his investigations included a determination of the fatigue properties.

The properties of copper and copper alloys for locomotive fire-box construction have been reviewed in great detail by

1. F. Benard, Amer. Inst. Min. Met. Eng. Tech. Pub. No. 909. (*Metals Technology* February, 1938).
2. *Metal Ind.*, Lond. 1938, 52, 389.
3. American Metal Co. British Patent 477,720.
4. Societé Generale Metallurgique de Hoboken. British Patent 480,107.
5. M. G. Corson. Amer. Inst. Min. Met. Eng. Tech. Pub. 932. (*Metals Technology* June, 1938.)
6. C. H. Lorig, F. B. Dahle, and D. A. Roberts. "*Metals and Alloys.*" 1938, 9, 63.
7. C. G. Goetzel. Amer. Soc. Metals. 1938. Preprint.
8. L. Northcott. *J. Inst. Met.* 1938, 62, 101.

Cook,[9] who also included the results of much experimental work, such as the determination of strength properties at elevated temperatures, annealing characteristics, and fatigue and certain other stress reversal tests. Cook also dealt with the advantages of Kuprodur, a temper-hardening copper-nickel-silicon alloy, which has been specially developed for locomotive fire-box purposes.

Some interesting observations on the recrystallisation of copper have been made by Cook and Macquarie,[10] special attention having been directed to the factors giving rise to the development of abnormally large crystal grains during annealing.

Welter[11] has dealt with the creep of copper at temperatures of $-60°$ up to $70°$ C.

Properties of Brass

In view of the great importance now attached to grain-size control in wrought alpha brasses, particularly in strip and sheet forms, the experience of Gonser and Heath,[12] in connection with the addition of small amounts of chromium, is of much interest. As pointed out in the discussion of this paper, however, there may be practical difficulties in this method of achieving fine-grained products, and in any case there will be sacrifice of ductility.

The influence of cold-working and annealing on the more general mechanical properties of the alpha brasses has been well known for many years, but Koster and Rosenthal[13] have recently studied the effect of variation in working and annealing treatments on the modulus of elasticity and on the damping capacity of brass having a composition of 72% copper, 28% zinc. They report that the modulus of elasticity is at a maximum—i.e., $16{\cdot}5 \times 10^6$ lb./sq. in. in the annealed condition, and that the reduction brought about by cold-working is of a more or less progressive order, the value obtained with a rolling reduction of 60% being about $14{\cdot}3 \times 10^6$ lb./sq. in.

A general consideration of the physical factors involved in the casting of high-tensile strength brass has been undertaken by Newson,[14] while Duma[15] has investigated the influence of manufacturing variables in the production of castings of a type of high-tensile brass for trunnion bearings.

The effect of variations in the composition and structure of alpha-beta brasses on their mechanical properties has been studied by Unckel,[16] with particular reference to front and back-end differences arising from extrusion conditions.

Nickel brasses of the type represented by alloys having compositions of approximately 45% copper, 45% zinc, 10% nickel, sometimes with a small amount of lead also present, are known to have excellent hot-working properties, so that they may be fabricated by extrusion and by hot-stamping. The influence of compositional changes on the hot-working characteristics and on mechanical properties has been investigated by Cook,[17] the general conclusion being that appreciable departure from the above composition is not commercially possible without a sacrifice of colour, workability, or other features.

Properties of Tin Bronzes

Some two years ago it was established that the alpha solid solubility limit of the copper-tin series did not extend above about 2% at ordinary temperatures, although the solid solubility amounted to more than 15% at 500° C.; this form of diagram indicates the possibility of the alloy series being amenable to heat-treatment. A group of recent patents[18] has been concerned with the improvements in electrical conductivity brought about by a low-temperature heat-treatment. In particular, it is possible to improve the electrical conductivity of hard-drawn 10% phosphor-bronze wire without encountering any loss of strength or hardness.

It has always been accepted that the tin bronzes have poor hot-working properties, and the limiting tin content for hot-working has usually been placed at 3%, a figure which has been confirmed recently by Davis and Hook.[19] Last year it was established that the tin content could be raised to a much higher figure if iron together with chromium or vanadium were added; more recently it has been claimed that copper-tin-manganese alloys containing 2–20% tin and 0·25–5% manganese may be hot-worked with comparative ease.[20]

For castings, Stewart[21] has provided some useful data on the creep properties of two commercial bronze alloys, one of which corresponded roughly with Admiralty gunmetal, while the other was a leaded gunmetal. He established the suitability of such alloys for service at temperatures up to about 260° C., although at higher temperatures their limiting creep loads were found to be of a very low order.

Kihlgren[22] has published the results of a comprehensive investigation on the production and properties of nickel bronze castings having a composition of 88% copper, 5% tin, 5% nickel, 2% zinc. By suitable quenching and tempering, castings may be made with a Brinell hardness of over 190, a tensile strength up to 40 tons/sq. in., and an elongation of 10% on 2 in.; it is, however, essential to exclude lead as an impurity and also to have sound castings in the first place. The much superior properties of such castings, as compared with those obtainable from ordinary gunmetal, indicate the possibility of their being widely used in the future.

Fleck and Bunch[23] have investigated the influence of heat-treatment on closing the porosity of bronze castings of the gunmetal type; the recommended heat-treatment was 2 hours at about 725° C. This method of reclaiming leaky castings is not viewed with great favour in this country, but Fleck and Bunch state that the above treatment only results in slight changes in mechanical properties, the chief of which is a decrease in hardness due to absorption of the delta phase.

Copper-Lead Bearings

The production of copper-lead bearings for high-duty bearing applications has been further extended, and Ness[24, 25] has claimed considerable improvements by addition of up to 1% lithium to the alloys; Osborg[26] has also dealt with this matter. One of the principal causes of lead segregation and poor structures in cast bearings is considered to be due to the presence of hydrogen dissolved in the molten alloy, and as lithium forms stable hydrides it is claimed to be possible to remove the hydrogen and so reduce segregation tendencies. Moreover, lithium, being practically insoluble in the solid state, will not reduce the thermal conductivity of the product, a matter which is of major importance, although it is often overlooked in the commercial production of copper-lead bearings.

McCarrol and Jeter[27] have described the manufacture of copper-lead bearings according to the Ford method, which consists of coating steel strip by passing it through a bath of molten copper-lead alloy. General reviews of other production methods have been given by Lay[28] and are also contained in a publication of the Deutsches Kupfer Institut.[29]

The production of copper-lead bearings from powdered metals is also receiving attention, and an attractive suggestion is that a spongy copper matrix formed from copper

9. M. Cook. Inst. Loco. Eng. 1938. Preprint.
10. M. Cook and C. Macquarie. Amer. Inst. Min. Met. Eng. Tech. Pub. No. 974. (*Metals Technology*, September, 1938.)
11. G. Welter. *Z. Metallk.* 1938, 30, 195.
12. B. W. Gonser and C. M. Heath. Trans. Amer. Inst. Min. Met. Eng. 1938, 128, 378
13. W. Koster and K. Rosenthal. *Z. Metallk.* 1938, 30, 345.
14. J. E. Newson. Inst. Brit. Foundrymen. 1938. Preprint.
15. J. A. Duma. *Metals and Alloys.* 1938, 9, 139.
16. H. Unckel. *Metallwirtschaft.* 1938, 17, 389.
17. M. Cook. *J. Inst. Met.* 1938, 62, 139.
18. B.T.H. Co. Brit. Patent 486,690; also U.S. Patent 2,128,122, and German Patent 659,207.
19. C. H. Davis and I. T. Hook. *Wire and W. Prod.* 1938, 13, 665.
20. D. R. Hull and American Brass Co. U.S. Patent 2,105,945.
21. W. C. Stewart. *J. Amer. Soc. Nav. Engrs.* 1938, 50, 107.
22. T. E. Kihlgren. Trans. Amer. Fdy. Assoc. 1938, 46, 41.
23. H. Fleck and T. C. Bunch. Amer. Fdy. Ass. 1938. Preprint.
24. H. Ness. Brit. Patent 485,523
25. H. L. Ness. *Metal Progr.* 1937, 32, 678.
26. H. Osberg. *Metal Progr.* 1938, 33, 43.
27. R. H. McCarrol and E. C. Jeter. *Automot. Industr.* 1938, 78, 205.
28. E. Lay. *Metallwirtschaft.* 1938, 17, 1,199.
29. "Lead Bronzes." Deutches Kupfer Institut. 1938.

powder sintered on the steel base should be prepared, and that this should be immersed in molten lead, when the lead would flow by capillary action into the pores of the copper matrix.

Copper-Chromium Alloys

Much attention has been given to copper-chromium alloys having a chromium content of 0·5–0·8%, sometimes with small amounts of beryllium, silicon, silver, and other elements in addition. The properties of these alloys have been described in some detail by several authors, including Brace,[30, 31] Corson,[32] and Davis.[33] An outstanding feature of chromium-copper is that it may be heat-treated to develop an electrical conductivity of the order of 80%, with enhanced mechanical properties, and on this account the commercial alloys are proving to be of considerable service for special electrical purposes. Another feature is that in the temper-hardened state chromium-copper has a useful strength at elevated temperatures, and although its creep properties have not yet been fully investigated the marked superiority of this material over copper is clear from some creep figures published by Brace.[31]

Flinn and Norton[34] employed chromium-copper, amongst other temper-hardening alloys, in their experimental observations on changes which occur in the damping capacity of alloys as a result of precipitation-hardening treatments.

Alloys for Electrode and Contact Purposes

The severe service conditions imposed on contact electrodes in resistance welding have necessitated considerable experimental work during the past few years, and many special copper alloys have been developed for this particular application. The behaviour of certain of the more widely used alloys, including copper-cobalt-beryllium, chromium-copper and others, has been reviewed by Harrington,[35] from whose record of the maximum service temperatures suitable for the various materials it is apparent that the copper alloy with 2·6% Co. and 0·4% Be. is quite satisfactory for long-period service at temperatures up to 400° C.; chromium-copper was indicated as being suitable for temperatures up to 350° C. Alloys with smaller quantities of cobalt and beryllium—i.e., about 0·5% cobalt and 0·3% beryllium, have been suggested for use as electrodes,[36] while for electrical contact purposes copper-cadmium alloys containing nickel and silicon to render them heat-treatable have been proposed.[37]

Other Electrical Alloys

The development of a conductor material having the maximum strength consistent with ease of manufacture by hot rolling and drawing at high speeds, and having at the same time a fair conductivity, has been described by Davis and Hook.[19] Alloys of copper with aluminium, silicon and tin were investigated, and an alloy containing 2·5% aluminium and 1·75% tin, giving a tensile strength of over 60 tons/sq. in. with an electrical conductivity of 17% was finally selected.

Copper nickel-manganese alloys, known as Manganin, have long been of interest in the electrical industry, principally because of their low-temperature coefficient; the influence of heat-treatment on electrical properties has now been studied by Schulze.[38]

Copper-Silicon Alloys

The copper silicon alloys, known as silicon bronzes, are being increasingly used in industry, and both Gillett[39] and Thum[40] have given general surveys on the properties and manufacture of these groups of alloys. One of the outstanding features is the readiness with which welding may be carried out, and this point has undoubtedly been of much assistance in the commercial exploitation of the alloys; reference to recent papers on the welding of silicon bronzes is made later.

Developments with other Alloy Groups

Relatively little use has in the past been made of manganese as an alloying element in copper alloys, although it has been realised, of course, that the mechanical properties of some of the alloys are superior to those of many of the better-known copper-base alloys. Following experimental work on the production of high-purity manganese at an economic price, Dean[41] has forecast a much greater use of manganese as an alloying element in copper alloys. It might be noted that copper-manganese-cadmium alloys containing up to 11% manganese and 3% cadmium, have recently been suggested for applications, particularly in steam atmospheres, involving corrosion and inter-crystalline attack.[42]

Copper-base alloys containing nickel and aluminium additions are of interest mainly on account of their heat-treatment possibilities and further American patents[43] have been secured covering certain brasses. The recent investigations on the constitution of the ternary copper-nickel-aluminium series by Alexander,[44] and Bradley and Lipson[45] are of great help in view of the commercial interest now attaching to these alloys.

With titanium and nickel additions to copper there is also a response to heat-treatment and alloys within the range of 1 to 10% titanium and 2 to 50% nickel are covered in a recent patent.[46]

The addition of tellurium and of selenium to copper-base alloys for the purpose of improving machinability, has been studied by Smith,[47] and by Burghoff and Lawson.[48] The principal advantage attending the use of these elements, instead of the usual lead addition, is that the hot-working characteristics are not greatly impaired. The conductivity is little affected, and as many parts employed in the electrical industry involve a considerable amount of machining, it is considered that the new free-machining types of copper, which can thus be obtained by the incorporation of approximately 0·5% of tellurium or selenium, will be very useful.

Resistance to Oxidation and Corrosion

In view of the corrosion-resisting properties of copper alloys and the large number of commercial applications involving corrosion services, a certain number of new developments and first-class reviews are naturally provided in most years. May[49] has contributed a survey of progress with regard to condenser tube corrosion, while two German textbooks on corrosion[50, 51] usefully summarise present knowledge on the subject of corrosion generally.

A further report on the A.S.T.M. investigations on the atmospheric corrosion of non-ferrous metals and alloys has appeared, after exposure of the specimens for six years in various situations.[52] Copper and most of the copper alloys, with the exception of certain brasses, suffered only slight losses of strength or ductility under any of the conditions.

Price and Thomas[53] have made a careful study of the oxidation of copper-aluminium alloys at high temperatures, and by a special selective oxidation treatment, so as to develop protective films, they have been able to improve

30. P. H. Brace. *Elect. J.* 1938, 35, 107.
31. P. H. Brace. *Metals and Alloys.* 1938, 9, 311.
32. M. G. Corson. *Iron Age.* 1938, 142 (15), 78 and (16) 25.
33. C. H. Davis. *Wire and W. Prod.* 1938, 13, 565.
34. R. A. Flinn and J. T. Norton. Amer. Inst. Min. Met. Eng. Tech. Pub. 914. (*Metals Technology*, April, 1938.)
35. R. H. Harrington, Welding J. (*Research Supp.*). 1938, 17 (10), 18.
36. F. R. Hensel, E. I. Larsen, and P. R. Mallory, Inc., U.S. Patent 2,131,475.
37. F. R. Hensel and P. R. Mallory, Inc. U.S. Patent 2,124,974.
38. A. Schulze. *Metallwirtschaft.* 1938, 17, 437.
39. H. W. Gillett. Amer. Fdy. Ass. 1938, 46, 413.
40. E. E. Thum. *Metal Progr.* 1938, 33, 258 and 389.
41. R. S. Dean. Amer. Soc. Metals. 1938. Typescript Preprint.
42. A. H. Stevens and American Brass Co. Brit. Patent 483,407.
43. E. L. Munsen and American Brass Co. U.S. Patents 2,101,087, 2,101,625, and 2,101,626.
44. W. O. Alexander. *J. Inst. Met.* 1938. Preprint.
45. A. J. Bradley and H. Lipson. Proc. Roy. Soc. 1938, 167, 420.
46. N. B. Pilling, P. D. Merica, and International Nickel Co. U.S. Patent 2,102,238
47. C. S. Smith. Trans. Amer. Inst. Min. Met. Eng. 1938, 128, 325.
48. H. L. Burghoff and D. E. Lawson. Trans. Amer. Inst. Min. Met. Eng. 1938, 128, 315.
49. R. May. Trans. Inst. Mar. Engrs. 1938, 50, 35.
50. O. Bauer, O. Krohnke, and G. Masing. "Corrosion of Metallic Materials, II.—Non-Ferrous Metals and Their Alloys." Hirzel, Leipzig.
51. A. Siegel. "Corrosion of Iron and Non-Ferrous Metals.—Service Experience in Electric Power Stations and Ships." Springer, Berlin.
52. Report of Committee B. 3. Amer. Soc. Test. Mat. 1938. Preprint.
53. L. E. Price and G. J. Thomas. *J. Inst. Met.* 1938. Preprint.

the oxidation resistance of such alloys to quite a considerable extent. The oxidation of beryllium-copper has been investigated by Terem.[54]

Some Commercial Applications of Copper

It is only possible to include three comparatively small, but nevertheless interesting, uses of copper in this section. The first concerns copper moulds for the casting of various metals and alloys; an excellent review of the present position has been made by Scherzer,[55] while more recently Erichsen[56] has described a new type of copper water-cooled mould for the casting of flat slabs of brass and other metals. It is claimed that this method of casting, followed by machining of the upper surface, is more satisfactory and economical than the casting of vertical ingots.

The second is the application of copper powder in industry. The production of porous bronze bearings and of copper-tungsten electrodes for spot welding has been reviewed by Hoyt.[57] The manufacture of self-lubricating bearings from copper-lead powder mixtures containing certain organic compounds is the subject of a recent patent,[58] while a further patent[59] is concerned with the manufacture of copper strip and sheet from powders.

Lastly, electro-deposition methods for producing various fabricated components have been extended, and a recent interesting idea is the production of gauze cloth by the deposition of copper on to photo-engraved cylinders. This gives a deposited strip with extremely accurate perforations, and the fact that there are no "kuckles," as in the case of woven wire mesh is an advantage for certain screening or sieving purposes.

Joining Practice—Soldering and Blazing

Soldering, silver-soldering, and brazing are so well established that it might have been thought that there was little need for further investigation; however, some recent papers reveal that many interesting developments are occurring. Chadwick[60] has investigated the strength of soft-soldered joints made with various types of copper, and observations were particularly directed to the strength of such joints after ageing at slightly elevated temperatures. It was found that there was a serious deterioration in the strength of joints made with tin solders on certain commercial varieties of copper, especially arsenical tough pitch copper; joints made with lead-silver solders were found to be quite stable.

Silver soldering and brazing are now being performed by means of resistance heating, and this promises to be a development of first-class importance. Reed and Edelson[61] have given an interesting description of resistance-brazing practice, using carbon electrodes, and the future possibilities of this production method are clearly indicated in this paper.

The brazing of completely assembled articles is now frequently performed by heating in controlled atmosphere furnaces. The size of article and the number of joints made are continually being increased, as engineers become familiar with the consistent quality of the joints and with the economies of this process. Some idea of the savings which can be effected may be obtained from the recent description by Weir and Webber[62] of the production of boiler units with over 1,000 copper tubes, all of which were jointed with silver solder in one heating operation.

Joining Practice—Welding

Whereas in this country the welding of copper and copper-base alloys is mostly carried out by means of the oxy-acetylene process, in America electric-arc methods are more favoured.

The carbon arc-welding of copper-silicon alloys has been investigated by Bunn, Hunter, and Seidlitz,[63] and also by Vreeland.[64] These researches show that very high welding speeds may be attained in welding copper-silicon alloys by the carbon-arc process, these being up to 10 in. per min.; there is no difficulty in securing joint strengths of about 24 tons/sq. in. in the as-welded state, although peening is recommended.

Carbon-arc methods of welding copper have been investigated by Hook and Swift,[65] in addition to Vreeland.[64] Copper welding practice in America is apparently very different from that ruling in England, since most American products are made in tough pitch copper (as is the German practice), while the joints are usually made with bronze filler rods, the tin contents of which often range up to 8%. Hook and Swift have made some interesting comparisons between tough pitch and deoxidised base materials when using a range of filler rods, including various deoxidised coppers, tin bronzes, and silicon bronzes. Their work provides ample evidence that deoxidised copper is a better base material, while a further finding is that the copper welding rods must contain definite amounts of deoxidants in order to counteract the pick-up of oxygen, which is much more serious when using the carbon-arc welding process than with the oxy-acetylene method. The best results reported by Hook and Swift were obtained with filler rods containing about 3% of silicon. While much of the work by Hook and Swift is not of direct practical application to British practice, it may nevertheless stimulate interest in carbon-arc welding in this country, as there are clear indications that the carbon-arc autogenous welding of copper would be quite feasible with copper filler rods containing approximately 0·25% silicon, so as to counteract oxygen pick-up.

The metallic arc welding of copper has made further progress in Germany, and the shielded arc electrodes developed by Lessel are now employed for the welding of staybolts in locomotive fireboxes.[66]

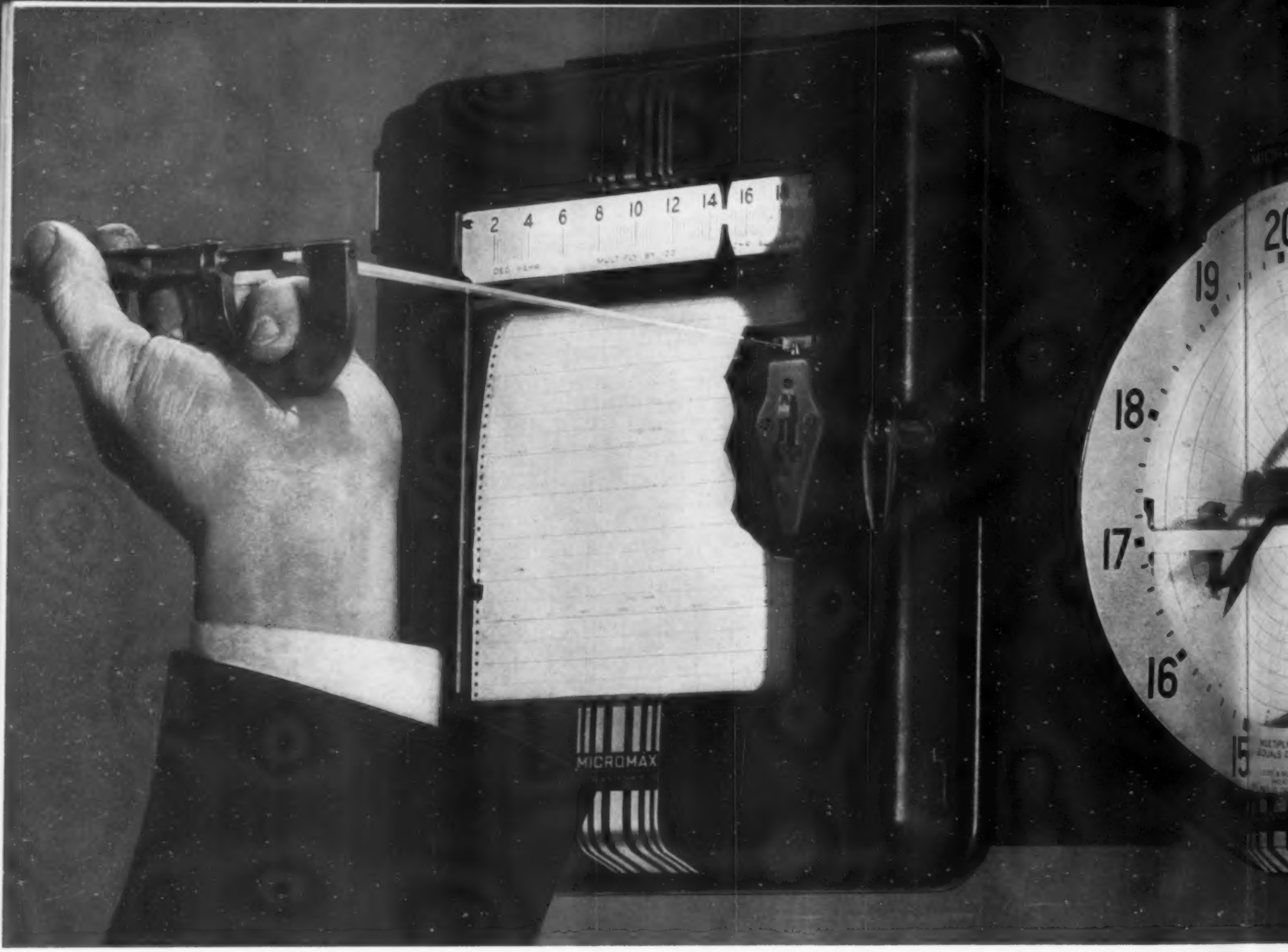
54. H. N. Terem. *Bull. Soc. Chim.*, France. 1938, 5, 589.
55. K. Schezer. *J. Birm. Met. Soc.* 1938, 18, 81.
56. S. F. Erichsen. *Met. Ind.*, Lond. 1938, 53, 251.
57. S. L. Hoyt. *Metal Progr.* 1938, 33, 157.
58. Continental Oil Co. Brit. Patent 488,590.
59. Hardy Metallurgical Co. U.S. Patent 2,134,366.
60. R. Chadwick. *J. Inst. Met.* 1938, 62, 277.
61. W. Reed and L. Edelson. *Welding J.* 1938, 17 (3), 26.
62. A. W. Weir and H. M. Webber. *Welding J.* 1938, 17 (10), 50.
63. E. S. Bunn, J. R. Hunter, and W. G. Seidlitz. *Welding J.* (Research Suppt.) 1938, 17 (10), 1.
64. J. T. Vreeland. *Welding J.* 1938, 17 (7), 20.
65. I. T. Hook and C. E. Swift. *Welding J.* (Research Suppt.). 1938, 17 (10), 48.
66. Deutsches Kupfer Institut. "One Hundred Years of Copper Fireboxes in Steam Locomotives." 1938.

Journal of Institute of Metals, Vol. LXII

THIS volume of the Journal of the Institute of Metals well maintains the standard set by its predecessors. In addition to the stimulating Presidential Address by Dr. C. H. Desch, F.R.S., entitled, "A Chemist's View of Metallurgy," the book contains twelve original papers, with discussions, on questions of great theoretical and practical importance in the field of non-ferrous metallurgy. These papers deal with such diverse subjects as the age-hardening of aluminium alloys, the crystallisation of copper, the physical and mechanical properties of nickel-brasses, magnesium alloys, rolled molybdenum sheet, the creep of tin and its alloys, porosity in hot-tinned coatings on copper, and soft-soldered joints. Powder metallurgy, which is becoming of such increasing importance, is represented by a contribution from the General Electric Co., Ltd., on copper-nickel-tungsten alloys sintered with a liquid phase present. The volume concludes with Professor G. I. Taylor's May Lecture on "Plastic Strain in Metals," in which the author describes his work with Dr. C. F. Elam on the straining of metallic single crystals, and discusses the application of experimental results with single crystals to polycrystalline aggregates.

Like the previous volumes, the book is excellently produced, well bound, the diagrams are clear, and the photographs are printed on excellent quality paper.

Edited by S. C. Guillan; published by the Institute of Metals, 4, Grosvenor Gardens, S.W. 1; price 31s. 6d.



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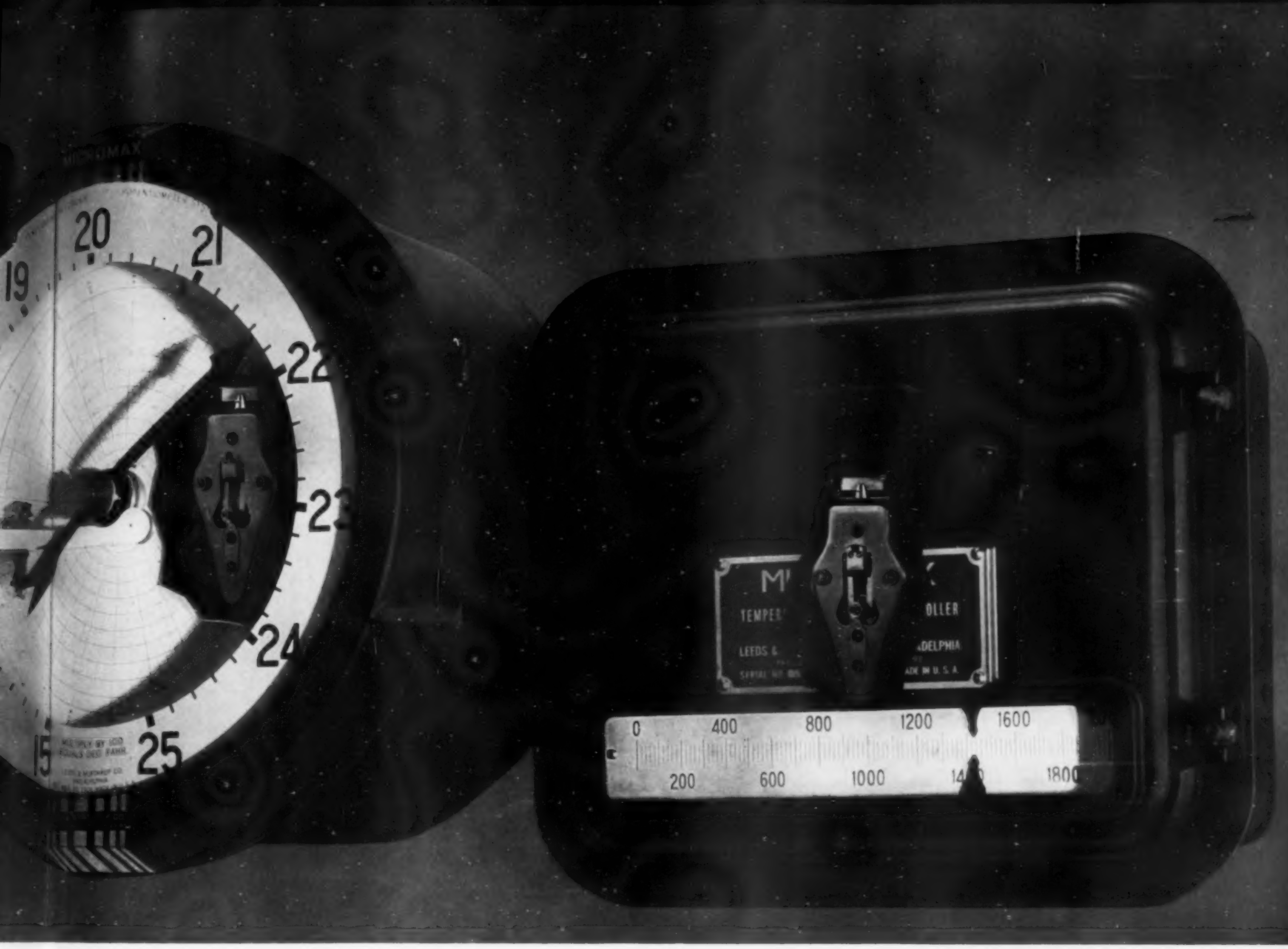
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Relationship Between the Mechanical Properties and Results in Service*

By L. W. Schuster, M.A.

None of the properties determined in the most commonly adopted mechanical tests is an important factor in causing a normal failure of service. The usual failure is due to faulty design or work-manship, carelessness in operation, or such causes as torsional or other forms of vibration. In this article the Izod test is discussed in relation to results in service.

IT is a mistake to assume that, just because the same load is applied to similar parts of different material, the stress is always the same in each. Fig. 11 on the left, shows stress-strain diagrams for two materials, and, at the right, the corresponding stresses when a bending moment is applied to a part with a smooth surface. As the elastic modulus of all steels is sensibly the same, the strain in any steel will be the same up to the yield point. The sketch at the right shows that in steel B, as soon as the yield point is reached, the stress remains constant, while in steel A the stress rapidly rises; this applies to a part such as a crane hook under proof loading. Should the part be a shaft, a fillet or any other discontinuity at the surface may readily cause the yield point of material B to be reached locally.

The Izod Test

As has been established, the result of the Izod test does not essentially show the capacity of material for withstanding impact. The velocity of any such notched-bar test, as usually applied, is far too low for such a purpose. Though the result depends upon several factors, on which it is not the purpose of this paper to enlarge, it may be said that the final stage of the test does afford an indication of the ease with which a crack, after it has once formed, will spread through metal. This phase of the test is related to service failures inasmuch as, when an incipient crack breaks out in a machine part, there is certainly an advantage for the material to have a high resistance to the spread of the crack. The more rapid the spread of a crack, the greater the chance that it will be discovered before the whole section of the part is broken; otherwise, severe consequential damage may readily take place to other important parts of the engine or machine, and human life may often be jeopardised.

Those responsible for the safe working of a boiler plant particularly have to guard against the use of material in which a crack will extend at a dangerous rate. In tough material a crack may be in existence for a considerable period before final fracture takes place, and this allows discovery during a periodical inspection before the crack has become dangerous. Causes leading to discovery are audible knocking of the running part, overheating of journals, or the issuing of oil from the end of a hollow part, or cracks are commonly found during a periodical inspection.

A practical demonstration is furnished by the hydrostatic testing to destruction of welded vessels. Where the welded material has given a high Izod value, the crack in the longitudinal seam, when once formed, has spread at a comparatively gradual rate through the metal, but where the Izod value has been low, sudden rupture has taken place through a series of incipient cracks. Fig. 12 shows weld metal containing an unrefined layer at the top. After the specimen had been slightly deformed a crack was set up; this suddenly jumped through the coarse metal, but it was immediately held up when it reached the refined lower runs.

In considering the usual failure of service, it is evident that the earlier part of the notched-bar test is of far the greater importance, in so much as the energy expended during the early stages of fracture shows the relative capacity of different materials to deform at a notch without initial cracking, and therefore, in a measure, shows their capacity for standing up to stress concentration at a notch. The test, when results are duly considered, certainly

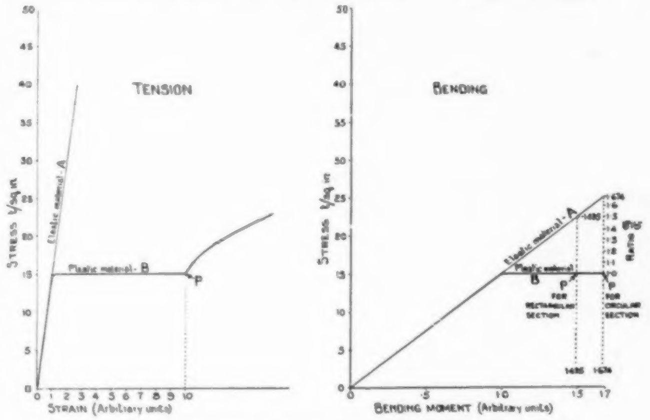


Fig. 11.—Comparison of stress at the outer fibres of a beam; elastic material v material stressed beyond the yield point.

shows the capacity of a material to deform without extension of the initial crack into the body of the specimen. It must be agreed, however, that the Izod test, which gives an integrated value expended during all stages of the test, is a clumsy method of obtaining this information. The energies can however, always be separated out by making load-deflection diagrams or from prior knowledge of the class of material. Useful information is also obtainable for mild steels by an examination of the surfaces of fracture. Though the general fracture may show crystal-line facets, a structural mild steel, if it offers a

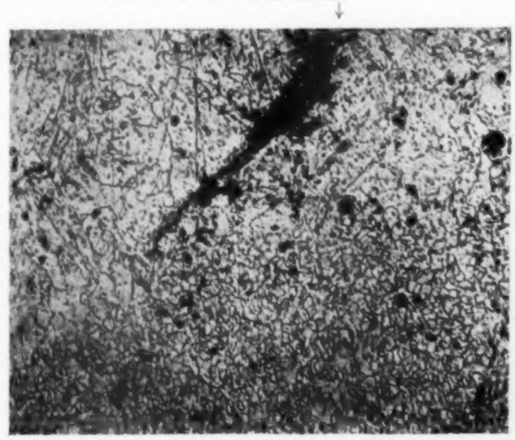


Fig. 12.—Weld metal containing an unrefined layer at the top. × 75

* Continued from November issue, p. 28.

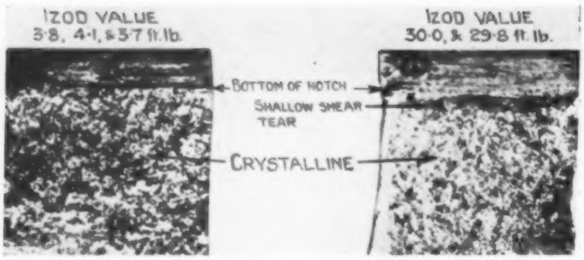


Fig. 13.—Fracture surfaces of two specimens following Izod tests.

high resistance to failure, will show, just below the notch, a darker area, where failure has taken place in shear, as is shown by the specimen at the right of Fig. 13. The greater the resistance to the early spread of the crack, the deeper will be this area.

On the question of mass effect, I will just add that within limits it is to be presumed that a material offering a higher resistance than another to the initiation of a crack when in small section on an Izod test will offer the higher resistance when in large mass.

The relative behaviour of two entirely different steels, at the beginning of the test, is exemplified by Fig. 14. A diagram for a mild steel is superimposed on a diagram for a nickel-chromium steel. It will be seen from the bottom line of the Table that the overall Izod energy for the mild steel is under half that for the alloy steel, yet, at the stage at which the peak of the diagram is reached, the energy absorbed is appreciably the greater, as is shown in the top line. First failure takes place a little before the peak of the diagram is reached, and it is clear that the greater energy required for the first failure of the mild steel is due to its greater capacity for deformation with stresses above the yield point.

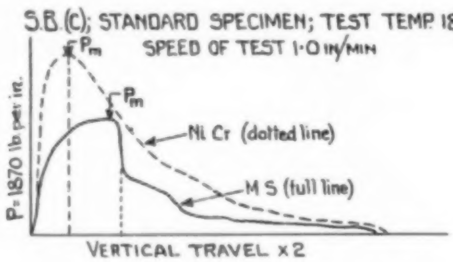


Fig. 14.—Comparison of energy.

Material.	I ft. lb.	E ft. lb.	Em ft. lb.	E after Pm ft. lb.	Pm ft. lb.
Ni Cr Steel	70	65	15·1	49·9	2,040
M.S. (Norm.) (C 0·35%)	30	33	21·8	11·2	1,230

The opinion has frequently been expressed by some of the most eminent and experienced authorities that failures are far more common in materials that give a low Izod value, and that a good Izod value is undoubtedly conducive to satisfactory behaviour. Such evidence cannot be ignored. If the evidence is accepted, it would seem to me that the significance cannot lie in the capacity of the test for detecting the resistance of material to the spread of a crack, which incidentally is often considered to be the prime value of the test. The brittle failure of a material may not take place till after an appreciable amount of energy has been expended, and moreover it does not commence before an initial crack has been formed. Seeing that when a material has developed even a minute crack, it has already mechanically failed, a high Izod value, arising from a good resistance to the spread of a crack, cannot reduce the number of failures. Consideration of this reasoning therefore, leads to the conclusion that the significance of the evidence must lie in the capacity of the test to discriminate between materials that offer good and indifferent resistance to the inception of a crack, i.e., under conditions of concentrated stress.

The point that I do emphasise is that if a crack breaks out in any machine part, no matter how small the crack may be or no matter what may be the cause, failure may certainly be considered to have taken place, for the crack, given time, will undoubtedly spread under the pulsating loads of service, and complete fracture of the part will be inevitable. This should also be borne in mind in considering the relationship between the Izod value and the liability to fracture of a part by shock. The value given by the notched-bar specimen is the overall value, and, if therefore an equivalent structural part with a notch is given a blow of intensity appreciably less than the test value, it may not be broken entirely, but a small crack may readily be initiated, which will spread during future service. This is a point that does not seem to be fully appreciated when test results are being considered.

The broken mild-steel crane hook, shown in Fig. 15, though it finally broke under a severe condition of service caused by snatching, contained two small cracks near the top. These had previously been set up, presumably, on some former occasion when the hook had been subjected to some milder condition of shock which had been insufficient to cause complete fracture owing to the good resistance of the metal. In contrast, Fig. 16 shows a poor quality W.I. link from a crane chain that suddenly broke across its full section. The notch this time was a portion of the figure 9, one of several numbers that had ill-advisedly been stamped on.

Fig. 15.—The fracture of a broken mild-steel crane hook.

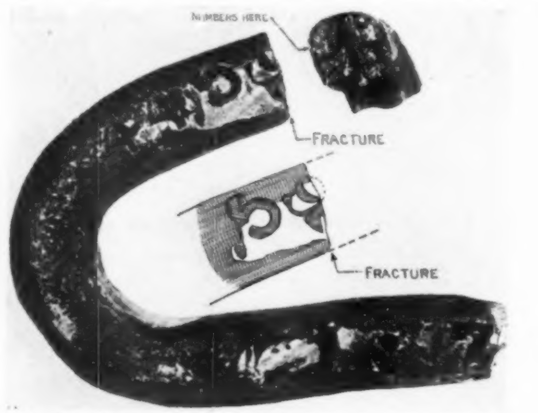


Fig. 16.—Fractured W.I. link from a crane chain.

In view of the unsatisfactory service that is often given by running parts with coarse structures, it may sometimes be considered surprising what satisfactory service is on, not infrequent occasions, given by mild steel with a grossly overheated structure. A few examples given in Figs. 17, 18, 19 and 20, illustrate this fact. Fig. 17 shows the overheated structure of a crankpin that gave a life of 25 years. Eventual failure was the result of slackness within the

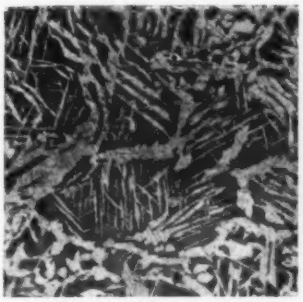


Fig. 17.—Overheated structure of a crank pin. × 50

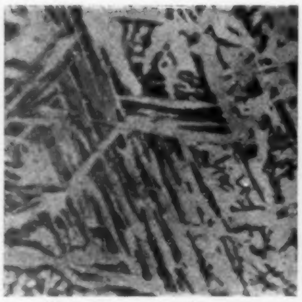


Fig. 18.—Overheated structure of a crank web. × 40

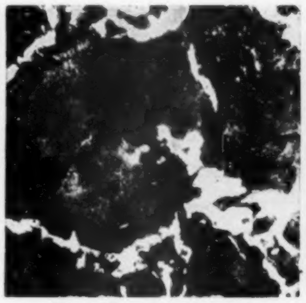


Fig. 19.—Overheated structure of a steam turbine shaft. × 75

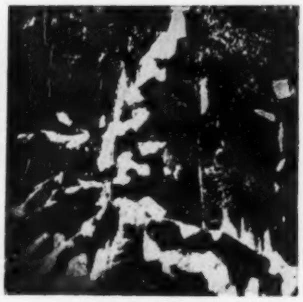


Fig. 20.—Overheated structure of a horizontal cross-compound steam engine shaft. × 150

crankarm. Fig. 18 shows the overheated structure of a crank web that gave a life of 35 years. The engine drove a rolling mill and had turned 520 million revolutions before failure, even though the stress in the web was double that usually allowed in an engine working under such arduous conditions as the driving of rolls. Fig. 19 shows the overheated structure of the shaft of a steam turbine, the carbon content of which was 0·58%. The life was only 16 years; though this age is considerably less than that of the shafts previously mentioned, it represents 6,000 million revolutions, or more than before, on account of the high speed of the turbine. Failure resulted from bad design and ill fit of the parts. Another example, Fig. 20, shows the overheated structure at the journal of a horizontal

STEEL FROM CRANKSHAFT—0.30% C.

	A Received Overheated.	Normalised.
Y; t/sq. in.	19·0	21·3
U; t/sq. in.	36·5	36·8
E; %	30·5	27·5
R; %	50·0	50·0
I; ft. lb.	3·8, 4·1, 3·7 Fracture completely crystalline.	48·7, 30·0, 29·8 Fracture fine crystalline, with fibrous area below notch.

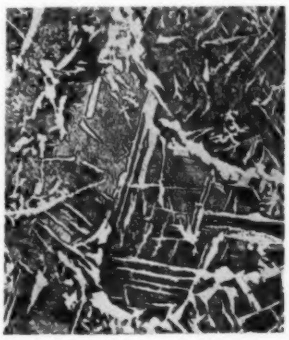


Fig. 21.—Overheated material of a broken crankshaft × 50

Fig. 22.—Showing an excellent bend test by an overheated material.

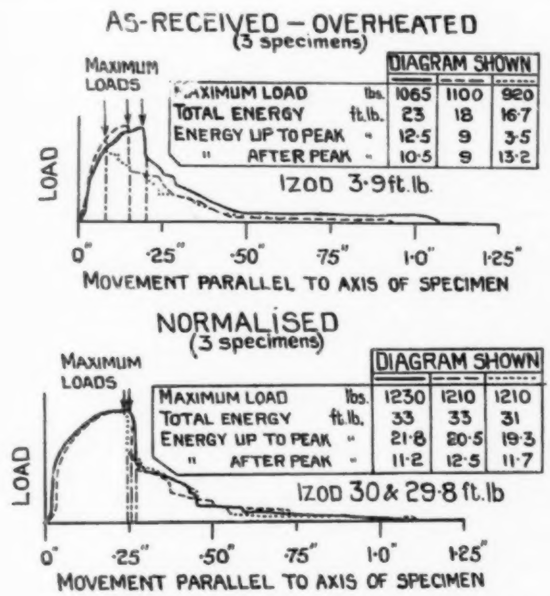


Fig. 23.—Diagrams for slow notched-bar tests on a 0.30% carbon steel from crankshaft.

cross-compound steam engine. The working stress, owing to an uneven distribution of load between the cylinders, was 9 t./sq. in., an excessive figure. Further, the steel was of poor ductility and toughness, and was unsuitable in so far as it had a sulphur content of 0·096%, and contained sulphide threads at the surface of the journals. In spite of all this the shaft had a life of 40 years, and was ultimately scrapped on account of the breaking out of surface cracks at the sulphur threads.

In considering such satisfactory experiences, two points come particularly to mind. Firstly, the fatigue value of a mild steel, when overheated, is no lower than when the structure is normal. The tendency is for the value to be higher, and therefore, with smooth surfaces, no concentration of stress and steady working conditions, there is no cause for the life to be reduced. Secondly, though such material may give a very low value in an Izod test, it is found that, when the other properties of the material are satisfactory, notched specimens of certain forms, when deformed at a slow rate, absorb a very satisfactory amount of energy; in other words the low Izod value is purely a speed effect, and a part working under favourable conditions of loading may thus give good service.

To give an example of speed effect Fig. 21 shows the overheated material of a broken crankshaft, the actual cause of the failure being torsional vibration. The material is certainly one that any manufacturer would desire to avoid. Tests were made to compare the mechanical properties of the material in the as-received overheated condition against those of the material after it had been given a normalising treatment to represent good works practice. The relative figures are given in the accompanying Table.

Attention is drawn to the fact that the tensile figures are virtually the same for each material, and that the

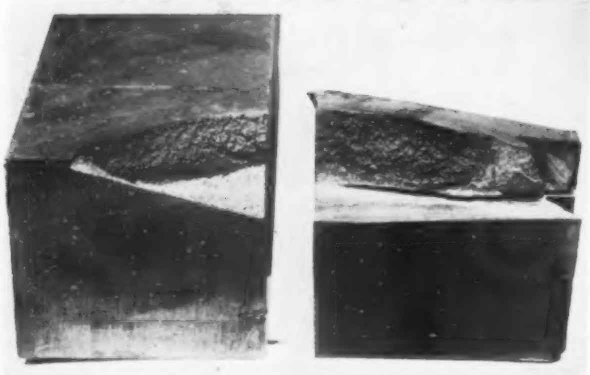


Fig. 24. (Top)—Failure of the web of the crankshaft of a concrete mixer.

Fig. 25. (Bottom)—Showing old cracks discovered in both webs.

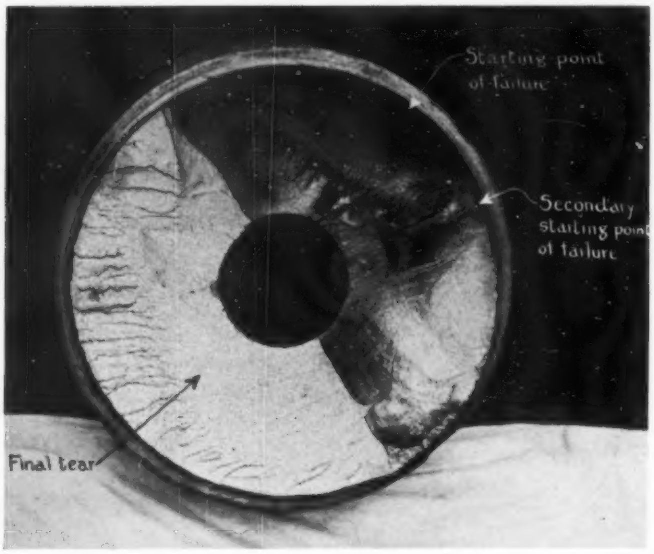


Fig. 26.—Showing failure of a crankshaft of about 20 in. diameter.

ductility of the material is exceedingly good. In spite of this, the Izod value of the overheated material is very low, though, for the material in the normalised condition, it is exceedingly good for a massive piece of carbon steel. The greater toughness of the normalised specimens is reflected by the fibre, which was visible below the notch of the broken Izod specimens ; the first normalised specimen, giving a higher value than the others, showed a greater amount of fibre at the fracture. A point that is particularly evident is that the low Izod value corresponds with the coarse micro-structure previously illustrated. Fig. 22 illustrates that the overheated material gave an excellent bend test, corresponding with the good reduction in area.

If diagrams for slow notched-bar tests on the material in the respective conditions of heat-treatment, are now compared, as in Fig. 23, it will be seen that each of three normalised specimens in the lower diagram give an energy of just over 30 ft. lb., or virtually the same as in the Izod test. The overheated material in the top diagram gives about 20 ft. lb., against about 3 ft. lb. for the Izod test. This is clearly a velocity effect. I am not going to discuss the tests in detail, but it is evident that the energy absorbed up to the peak of the diagram, i.e., before the crack starts to extend into the body of the specimen, varies in the different specimens. For two out of three of these tests, this value is quite respectable, and with still slower rates of loading the overheated material would probably have required almost as much if not as much energy as the normalised material. The lower value given by the third specimen is probably due to the presence of a particularly unfavourable grain at the root of the notch.

An interesting example of failure, shown in Fig. 24, is that of a web of the crankshaft of a concrete mixer that broke owing to a jam in the cylinder. Fracture started from the fillet of the crankpin, and the absence of any incipient creeping crack is to be particularly noticed. The unexpected feature was that the crankshaft broke, and not the teeth of the gear driving the mixer. The mystery might seem to be intensified by the discovery that old cracks, $\frac{5}{8}$ in. deep, shown in Fig. 25, existed in both webs, starting at a fillet of each journal. The explanation was simple : the fracture took place under shock, and the overall Izod value of the material was 3 ft. lb. only, the material thus having a very low resistance to the initiation of a crack. When the stress existing at the end of the stroke at which the jam occurred is calculated, concentration of stress being left out of consideration, it is found that the stress due to bending at the position of fracture was double that at the fillets from which the old cracks had started. Moreover, at the moment of failure the metal in the neighbourhood of the old cracks was in compression, and the cracks would have been closed up. At the position of fracture the metal of low resistance was under tension, and unable to withstand the impact at the change in section.

At this stage it may be of interest if I recall that some years ago my Company experienced an epidemic of the failure of crankshafts of about 20 in. in diameter, made by a particular manufacturer. The design and stress carried were in every way normal, and the failure was in no way due to any particular condition of running. The life usually lay between 15 and 20 years, and an example is shown in Fig. 26. On an occasion when a colleague happened to be watching an engine at work, he noticed that the crankshaft was of the manufacture in question. On ascertaining the age of the particular engine, he jokingly remarked to the owner that it would not be long before he had a smash, and sure enough the shaft broke shortly afterwards. In a metallurgical examination of several of these shafts I found only one common point at fault. The metal had been stewed in the furnace at a low temperature, and the pearlite had become globularised. The particular metal gave an elongation of 40% and a reduction in area of 60%. The Izod value had been reduced to 3 ft. lb. by the faulty heat-treatment.

This accumulated evidence does undoubtedly tend to show that certain materials with an abnormally low Izod value, yet satisfactory in other respects, can prove to be unsuitable for service in machine parts, even though they be steady running. As these particular shafts are not now made, I will not be doing the manufacturer any injury by saying that he had standardised the same pernicious heat-treatment for all his forgings, and that these had accordingly given the same unsatisfactory result in service.

(To be continued.)

The Behaviour of Sulphur in the Basic Open-Hearth Process

By D. Manterfield

The behaviour of sulphur in basic open hearth furnaces has been investigated, with particular reference to the distribution of sulphur between metal and slag and the influence of furnace operating conditions upon this distribution. A series of experiments is decribed and the results discussed; a volumetric method is described by which the sulphur content of basic slags may be accurately determined in a few minutes.

A SERIES of experiments has been carried out in the Templeborough Melting Shop of Messrs. Steel, Peech and Tozer to investigate the behaviour of sulphur in basic open hearth practice, with particular reference to the distribution of sulphur between metal and slag and the influence of furnace operating conditions upon this distribution.

Experimental

The furnace plant consists of 13 open-hearth furnaces each of 80 tons nominal capacity, using a cold (pig and scrap) charge. A large number of heats were observed; and slag and metal samples obtained at various intervals were analysed, and later correlated with the furnace charges and histories of the heats. It was noted at an early stage of the work that, with a normal balanced slag carrying approximately 51% lime and 12% silica, the ratio of slag sulphur to metal sulphur was invariably of the order of 10 : 1. It appeared, therefore, that there was a definite tendency to establish an equilibrium condition between the sulphur in slag and metal. Any change in furnace conditions resulting in the disturbance of equilibrium was followed by a gradual reversion back to the equilibrium condition.

Samples taken during the refining period showed that, under normal standard conditions, the 10 : 1 ratio was almost a maximum and was only attained when the correct temperature, basicity and fluidity of the slag had been obtained. The ratio was independent of the total amount of sulphur present, the minimum of the series being 0·019% sulphur in the steel with 0·22% in the slag, the maximum being 0·160% sulphur in the steel and 1·85% in the slag. The large amount of sulphur which a good basic slag can carry is worthy of note. Once the condition of the equilibrium is established, the degree of further desulphurisation is definitely limited. If the sulphur in slag is high, that in the metal is correspondingly high and from the figures obtained it is apparent that, after achieving the 10 to 1 distribution, the removal of sulphur then takes place very slowly. Thus, the time factor limits the amount of desulphurisation taking place after a good slag is obtained.

Calculation of Sulphur in Charge

In the investigations recorded, calculations were made of the total weight of sulphur in the charge, the weight of sulphur on melting and at various stages during refining. There was, as anticipated, an increase due to "pick-up" from the gas during the melting period, a further increase after lime and spar additions and then a slow and small diminution during refining. The "pick-up" after the addition of lime and spar was surprisingly large in some cases. In most instances the weight of sulphur present in the slag and metal at tapping was little less than that contained in the original charge, the quantity removed being variable but seldom more than that picked up from the gas.

Chart I gives a list of 46 heats with the metal and slag sulphur on tapping (before finishing additions), and the co-efficient Slag S./Steel S. For comparison the ingot steel sulphur figure is also given together with the co-efficient calculated from this figure. Also, appended are details of some typical heats showing particulars of the charge, the feed and the analyses of the slag and steel samples.

CHART I.

AVERAGE SLAG ANALYSIS.

SiO_2 12·5, Fe. 11·5, CaO 52·0, P_2O_5 4·5, MnO 4·5, MgO 5·0.

No.	Bath S.	Co-efficient Slag S. Metal S.	Ingot Steel S.	Co-efficient Slag S. Metal S.	Finishing Slag S	
1	0·019	11·6	0·019	11·6	0·22	
2	0·035	9·4	0·035	9·4	0·33	
3	0·043	9·3	0·040	10·0	0·40	
4	0·045	8·2	0·040	9·2	0·37	
5	0·049	8·5	0·042	10·0	.0·42	
6	0·038	8·8	0·042	8·1	0·34	Scale Fed
7	0·043	9·1	0·038	10·3	0·39	
8	0·039	9·5	0·041	9·0	0·37	Scale Fed
9	0·045	8·0	0·042	8·6	0·36	
10	0·041	9·3	0·042	9·0	0·38	Ore Fed
11	0·044	8·4	0·040	9·2	0·37	
12	0·039	10·3	0·039	10·3	0·40	
13	0·048	9·8	0·042	11·2	0·47	
14	0·043	9·1	0·036	10·8	0·39	
15	0·035	10·0	0·033	10·6	0·35	
16	0·053	9·1	0·046	10·4	0·48	
17	0·031	9·7	0·030	10·0	0·30	
18	0·048	8·0	0·038	10·1	0·385	
19	0·044	9·3	0·045	9·0	0·41	
20	0·046	9·8	0·044	10·2	0·45	
21	0·042	9·8	0·042	9·8	0·41	
22	0·042	8·8	0·036	10·3	0·37	
23	0·036	8·0	0·032	9·0	0·29	
24	0·047	9·6	0·044	10·2	0·45	
25	0·038	9·2	0·034	10·3	0·35	
26	0·047	9·4	0·044	10·0	0·44	
27	0·040	10·0	0·042	9·5	0·40	
28	0·042	9·5	0·040	10·0	0·40	
29	0·045	9·0	0·043	9·5	0·41	
30	0·054	7·4	0·043	9·3	0·40	
31	0·054	9·2	0·047	10·6	0·50	
32	0·045	8·2	0·042	8·8	0·37	
33	0·041	9·3	0·047	8·1	0·38	Slag SiO_2 17·0%
34	0·046	7·4	0·048	7·0	0·34	Slag SiO_2 17·3%
35	0·034	9·1	0·028	11·4	0·32	
36	0·038	10·5	0·039	10·3	0·40	
37	0·042	8·3	0·037	9·7	0·36	
38	0·040	9·6	0·037	10·4	0·385	
39	0·063	8·1	0·052	9·8	0·51	
40	0·046	9·6	0·043	10·2	0·44	
41	0·040	8·0	0·040	8·0	0·32	Sil. Slag
42	0·039	10·1	0·039	10·1	0·395	
43	0·039	9·9	0·038	10·1	0·385	
44	0·041	9·5	0·042	9·3	0·39	
45	0·039	9·2	0·035	10·3	0·36	
46	0·039	9·8	0·034	11·2	0·38	
Average ..		9·2		9·8		

Consideration of Results

Consideration of the figures obtained led to certain conclusions being formed as to the theory of desulphurisation. The basic reaction involved is :—

$$Ca\ O + Fe\ S \rightleftharpoons Ca\ S + Fe\ O$$

This reaction is reversible and proceeds to equilibrium under the prevailing conditions. If the Fe O was removed as formed the reaction from left to right could proceed to completion. Alternatively any addition to the Fe O content would result in the reaction taking place from right to left. Thus the oxygen content of the metal (in the form of Fe O) is, in the writer's opinion, a governing factor in the theory of desulphurisation.

CHART I.

CHARGE 32.

	Tons	Cwts.	Sulphur	Cwts. Sulphur
Basic Iron	19	0	0·03	0·11
Heavy Mill Scrap	68	10	0·04	0·55
Lime	4	3	0·10	0·08
Fluor Spar		14	0·25	0·035
Total				0·775 cwts.

being out of condition and hence not carrying its quota of sulphur. High sulphur melts may be due to several causes, such as high sulphur in the charge, bad charging, resulting in excessive pick up from the gas, poor slag formation and over-oxidation.

Low carbon in the melting sample is often accompanied by high sulphur, indicating excessive oxidation, due to a long melting-down period or other causes such as rusty scrap or low manganese in the charge, i.e., lack of deoxidants. When a high sulphur content accompanies a normal carbon melt, the slag is often silicious and therefore of low basicity; such slags being incapable of carrying their full quota of sulphur. If the basicity of the slag is reduced due to excessive silica content, sulphur tends to pass back from slag to metal. One example quoted from several observed instances was a charge with a sulphur content in the metal of 0·043% 15 minutes before tapping.

Time	Feed	Steel Sample.				cwts. S.	Slag Sample.					Cwts. S.	Total S. Cwts.
		C.	S.	P.	Mn.		SiO_2.	Fe.	CaO.	MnO.	S.		
11·20		0·58	0·026	0·055	0·43	0·42	8·94	8·00	54·04	6·70	0·215	0·37	0·79
11·25	42 cwts. Lime												
12·5	6 cwts. Spar												
12·25		0·53	0·025	0·044	0·40	0·40	8·80	8·80	55·02	7·05	0·21	0·54	0·97
12·25	20 cwts. Scale												
12·50		0·42	0·025	0·014	0·25	0·40	6·70	13·4	53·92	7·87	0·19	0·49	0·89
1·20	27 cwts. Ore												
2·40		0·08	0·022	0·010	0·18	0·35	6·40	18·0	48·2	7·01	0·19	0·51	0·86

FINISHING ADDITIONS.

Ferro Manganese (to ladle) .... 6 cwts.
Aluminium .... 6 lbs.

	C.	S.	P.	Mn.
Ingot Steel	0·08	0·020	0·016	0·38

CHART III.

CHARGE No. 27.

	Tons	Cwts.	Qrs.	Sulphur	Cwts. Sulphur
Basic Iron	17	18	0	0·07	0·25
Moulds	11	8	0	0·06	0·137
Mill Scrap	12	18	0	0·04	0·10
Heavy Steel Scrap	30	9	0	0·06	0·305
Turnings	5	12	0	0·05	0·056
Bundles	9	8	0	0·05	0·094
Ferro Manganese	—	4	0	—	—
Lime	4	2	0	0·10	0·08
Fluor Spar	—	14	0	0·25	0·035
Total Sulphur in Charge					1·117 cwts.

A portion of the roof came in—and the sulphur content rose to 0·055%.

The reduction of sulphur on the addition of ferro manganese is illustrative of the action of deoxidants in establishing the necessary equilibrium between metal and slag and is not due essentially to any reaction of the ferro manganese itself in removing sulphur. In the table of figures given it will be noticed that, in those cases where equilibrium conditions had been established before tapping, as indicated by the slag containing ten times the sulphur content of the metal, the finishing additions caused little or no decrease in the sulphur content of the steel. In the few cases where the slag and metal figures were not in the desired ratio, then a drop in sulphur did occur and the ratio of sulphur in the finished steel to that of the last slag sample was adjusted to the normal 1 to 10 relationship. Chart IV shows complete details of a typical charge

Time.	Feed.	Steel Samples.				Cwts. S.	Slag Samples.					Cwts. S.	Total S Cwts.
		C.	S.	P.	Mn.		SiO_2.	Fe.	CaO.	MnO.	S.		
10·5		1·06	0·030	0·123	0·61	0·48	18·86	3·65	55·58	4·31	0·27	0·46	0·94
10·10	42 cwts. Lime												
10·30	8 cwts. Spar												
10·45		1·05	0·025	0·105	0·59	0·40	17·86	3·10	60·9	3·74	0·255	0·60	1·00
10·46	54 cwts. Scale												
11·25		0·80	0·026	0·016	0·31	0·42	14·10	9·00	53·06	6·20	0·245	0·63	1·05
12·10		0·56	0·024	0·018	0·28	0·38	13·62	9·60	54·18	6·20	0·255	0·65	1·03

FINISHING ADDITIONS.

Ferro Manganese (to bath) .... 10 cwts.
,, ,, (to ladle) .... 2¾ ,,
,, Silicon (to ladle) .... 5¾ ,,

	C.	Si.	S.	P.	Mn.
Ingot Steel	0·56	0·224	0·024	0·026	0·80

It is well known that desulphurisation of steel in the basic open hearth process requires a non-oxidising, highly basic, fluid slag. This necessitates a sufficiently high temperature. Fluor spar assists by increasing the fluidity of the slag at a given temperature, apart from any other role it may serve. The presence of de-oxidants such as carbon, silicon, manganese, aluminium (and probably phosphorus) aids the attainment of equilibrium between metal and slag and promotes the condition wherein the slag carries its maximum proportion of sulphur. In most cases of sulphur trouble in basic open hearth practice equilibrium has not been established owing to the slag

on which this occurred. In the writer's opinion, manganese should not be regarded as a direct desulphuriser; the value of manganese in removing sulphur is due to its deoxidising power in reducing Fe O and thereby increasing the velocity of the desulphurisation reaction:—

$$CaO + FeS \longrightarrow CaS + FeO$$
$$\longleftarrow$$
$$FeO + Mn \longrightarrow MnO + Fe$$

The old method of adding pig iron and lime to reduce sulphur is explained on the assumption that silicon and manganese in the pig iron reduce the excess oxides whilst the lime increases the basicity of the slag and in addition takes up the silica formed by the oxidation of the silicon in the pig iron. When oxide (ore or scale) is added with the charge higher sulphur melts are a result on account of the higher state of oxidation of the bath. With a high carbon melt it is very rarely that sulphur trouble is experienced.

All these facts point to the state of oxidation of the bath being the chief factor governing desulphurisation and the attainment of equilibrium conditions between metal and slag.

The amount of sulphur actually removed from the charge by oxidation of the furnace gases is of very small proportions compared with that passing from steel to slag, more particularly when the sulphur content is normal. In the casts under observation approximately 0·10 cwt. of sulphur was removed by gaseous oxidation; this is a negligible quantity when calculated to a percentage of the charged weight.

However, similar calculations were made upon several casts (not included in this series) in which sulphide of iron was added with the charge, giving an abnormally high sulphur content. In these casts the sulphur loss due to gaseous oxidation was very considerable, as much as 1·16 cwt. of sulphur being eliminated during charging and refining. A detailed example is given of this type of charge in Chart VI.

Conclusions

The main features of this investigation are summarised below:—

1. A state of equilibrium between sulphur in the slag and sulphur in the metal tends to be established. When this state is attained the degree of further desulphurisation is very limited.
2. Maximum desulphurisation necessitates this state of equilibrium between metal and slag, involving control of temperature, basicity and slag condition.
3. As the state of oxidation of the bath is an important factor, over-oxidation should be avoided.
4. Early slag formation, when de-oxidants (C, Si, Mn) are present promotes early establishment of equilibrium.
5. In order to ensure a low sulphur product it is desirable to use raw materials as low in sulphur as possible.

introduced to reduce the small amount of ferric iron present which would otherwise prevent total evolution of the sulphur as hydrogen sulphide. This hydrogen sulphide is absorbed in a U tube containing 10 ml. of caustic soda solution (280 grams per litre); a trap is inserted between the evolution flask and the absorption tube to collect hydrochloric acid vapours.

The hydrochloric acid solvent is first introduced from the tap funnel slowly and gentle heat applied, more solvent being used and greater heat applied as solution

CHART IV.

CHARGE No. 35.

	Tons	Cwts.	Qrs.	Sulphur	Cwts. Sulphur
Basic Iron	8	19	0	0·07	0·125
Cast Metal	9	0	0	0·10	0·18
Heavy Steel Scrap	40	2	0	0·06	0·48
Turnings	7	14	0	0·05	0·077
Pit Scrap	8	5	0	0·05	0·08
Bundles	13	5	0	0·05	0·13
Anthracite Coal	0	3	0	—	0·01
Lime	4	3	0	0·10	0·08
Fluor Spar	0	14	0	0·25	0·035
Total S.					1·197

Time.	Feed.	Steel Samples. C.	S.	P.	Mn.	Cwts. S.	Slag Samples. SiO_2.	Fe.	CaO.	MnO.	S.	Cwts. S.	Total S. Cwts.
1·45		0·30	0·053	0·020	0·23	0·86	17·08	6·65	55·58	4·42	0·375	0·65	1·51
1·50	42 cwts. Lime												
2·25	8 cwts. Spar												
2·32		0·26	0·045	0·014	0·20	0·72	13·74	8·10	60·48	3·51	0·40	0·96	1·68
3·5		0·14	0·042	0·010	0·15	0·68	12·04	12·04	56·70	4·08	0·335	0·86	1·54
3·20							11·66	13·55	55·02	4·15	0·32		

FINISHING ADDITIONS.

Spiegel (to bath)	6 cwts.
Ferro Manganese (to bath)	10 cwts.
,, ,, (to ladle)	7 cwts.
Ferro Silicon (to ladle)	5½cwts.
Aluminium (to ladle)	30 lbs.

	C.	Si.	S.	P.	Mn.
Ingot Steel	0·16	0·202	0·036	0·016	0·70

CHART V.

CHARGE No. 30.

	Tons	Cwts.	Qrs.	Sulphur	Cwts. Sulphur
Basic Iron	9	6	0	0·07	0·13
Cast Metal	11	17	0	0·10	0·24
Mill Scrap	7	6	0	0·04	0·06
Heavy Steel Scrap	29	15	0	0·06	0·36
Light ,, ,,	4	10	0	0·06	0·05
Turnings	9	10	0	0·05	0·10
Bundles	8	1	0	0·05	0·08
Lime	4	2	0	0·10	0·08
Fluor Spar	0	14	0	0·25	0·03
Total					1·13 cwts.

Time.	Feed.	Steel Samples. C.	S.	P.	Mn.	Cwts. S.	Slag Samples. SiO_2.	Fe.	CaO.	MnO.	S.	Cwts. S.	Total S. Cwts.
9·25		0·42	0·058	0·078	0·31	0·94	20·48	3·25	55·72	3·26	0·255	0·44	1·38
9·30	56 cwts. Lime												
10·0	8 cwts. Spar												
10·20		0·40	0·037	0·037	0·29	0·60	15·90	4·35	61·60	2·87	0·375	0·93	1·53
10·30	14 cwts. Scale												
10·40		0·35	0·037	0·023	0·24	0·60	14·36	7·75	58·38	3·22	0·345	0·88	1·48
11·15		0·34	0·033	0·018	0·22	0·53	13·42	8·80	57·4	3·79	0·34	0·87	1·40

FINISHING ADDITIONS.

Ferro Manganese (to bath)	10 cwts.
,, ,, (to ladle)	3¼cwts.
Ferro Silicon (to ladle)	5½cwts.
Anthracite Coal	72 lbs.
Aluminium	15 lbs.

	C.	Si.	S.	P.	Mn.
Ingot Steel	0·33	0·196	0·035	0·019	0·71

Development of a Volumetric Method for Determining Sulphur Content

Incidental to this series of experiments a volumetric method was evolved by which the sulphur content of basic slags may be determined accurately in seven minutes. The method consists, briefly, in dissolving the slag in a 350 ml. evolution flask, using as solvent a 4% solution of stannous chloride in hydrochloric acid (sp. gr. 1·16). The evolution flask is fitted with a delivery tube and a tap funnel. One gram of powdered slag is taken and an equal weight of aluminium is dissolved with the slag, to generate hydrogen in order to carry over the hydrogen sulphide evolved. The stannous chloride in the solvent is introduced to reduce the small amount of ferric iron present which would otherwise prevent total evolution of the sulphur as hydrogen sulphide.

proceeds. The slag sample dissolves before the aluminium. On complete solution of the latter, by which time the liquid in the evolution flask is boiling, the U tube is detached (precautions being taken to prevent "sucking back"). The contents of the U tube are washed into a beaker, starch, as indicator, and dilute sulphuric acid added and the determination completed by titrating the liberated hydrogen sulphide with standard iodine solution containing 4·05 grams of iodine per litre. 1 ml. Std. iodine = 0·05% S on 1 gram.

CHART VI.

CHARGE No. 27/9.

	Tons.	Cwts.	Sulphur.	Cwts. Sulphur.
Basic Iron	5	9	0·07	0·076
High Sulphur Basic Iron	4	3	0·12	0·10
Hæmatite Iron	9	7	0·04	0·074
Mill Scrap	11	13	0·05	0·689
Heavy ,,	41	14	0·05	
Light ,,	5	12	0·05	
Turnings and Pit	10	0	0·05	
Ferro Manganese	0	10	—	—
,, Sulphide	0	16	23·0	3·68
Lime	4	1	0·20	0·16
Fluor Spar	0	13	0·20	0·026
Total S.				4·80 cwts.

Time.	Feed.	Steel Samples. C.	S.	P.	Mn.	Cwts. S.	Slag Samples. SiO_2.	Fe.	CaO.	MnO.	S.	Cwts. S.	Total S. Cwts.
16·25		0·41	0·116		0·23								
17·0		0·27	0·116		0·24								
17·10		0·21	0·118	0·014	0·23	1·93	14·0	9·5	48·4	10·15	1·23	2·43	4·36
17·10	26 cwts. Lime												
17·45	5 cwts. Fluor Spar												
18·10			0·093		0·23			13·0					
18·12		0·11	0·092	0·014	0·20	1·50	12·1	13·5	49·2	8·86	1·32	3·36	4·86
18·40		0·09	0·092		0·19	1·50	10·8	16·5	49·0	8·57	1·23	3·13	4·63
19·10			0·082		0·16	1·34	10·3	18·5	46·5	8·37	1·11	2·83	4·17
	25 cwts. Ferro Mn. to bath Sample and Slag 8 min. after		0·088		1·00	1·47	10·0	18·0	46·1	9·35	1·07	2·73	4·2[illegible]

FINISHING ADDITIONS TO LADLE.

Ferro Phosphide				$2\frac{3}{4}$ cwts.
Rock Sulphur				$3\frac{3}{4}$ cwts.
	C.	S.	P.	Mn.
Pit Sample	0·09	0·242	0·060	0·62

Since the completion of this work a similar method has been published, after independent research, by Maurer and Haderer* and their paper contains full details of the determination of sulphur in basic open hearth slags.

Consistent agreement of the above method has been obtained with the gravimetric method.

Canada's Aluminium Production

Canadian requirements of bauxite, the ore of aluminium, are all met by import, no commercial deposit having as yet been found in Canada. Direct delivery of bauxite from British Guiana, which was discontinued in 1930, was resumed in 1935 when 24,685 tons were imported; in each of the following years imports from British Guiana show marked increases, rising to 176,411 short tons in 1937. There are also substantial imports annually from the United States, and occasionally small amounts are re-exported from Great Britain, most of which is used in the abrasive and chemical trades.

The Aluminium Company of Canada, at its two refineries at Arvida and Shawinigan Falls, Quebec, is the only Canadian producer of the metal; most of the output is exported. This Company has also two fabricating plants, one at Shawinigan Falls, Quebec, and the other at Toronto, Ontario. A number of other plants, mainly in Ontario and Quebec, manufacture aluminium cooking utensils, automobile parts, and other articles of aluminium.

* E. Maurer and F. Haderer. *Journal of the Iron and Steel Institute*, No. 1, 1938.

"Loded" Cast Irons

A new range of high-duty grey cast irons, known as "Loded" irons, suitable for cylinder liners, piston rings, and other important engineering parts was described by Mr. H. J. Young recently before the Institute of Marine Engineers. These irons may be manufactured with any iron foundry's normal appliances, but metallurgical control is essential. They form an extension of that group of machinable metals known as grey cast irons, made in refractory or metal moulds, stationary or moving. In a grey cast-iron casting, it may be found that according to the rate of cooling the metal will be hard and white in one place and soft and grey in another. Between these two limits of fast and slow cooling, the metal will be in its best condition—namely, not too hard and white, and not too soft and grey. In fact, it will be all-pearlitic, but only round about the one section where the rate of cooling suits the particular quality of iron used.

In discussing this subject, the author defined the all-pearlitic state of iron, and showed that, theoretically, all-pearlitic grey iron contains nothing but pearlite plus free graphite flakes. No ferrite is present. With quicker cooling, free carbide known as cementite, will also be present. In this condition the quality of the iron is not impaired, and the two conditions described represent the author's definition of all-pearlitic iron as aimed at in practice—namely, iron either on, or on the *safe* side of, the theoretical all-pearlitic point. The reason for this is that traces of ferrite will profoundly affect the wearing qualities of the iron.

Continuing, the author discussed the effect of silicon on the rate of cooling, and gave percentages of silicon, nickel, and chromium in an all-pearlitic iron. Then he described the "Loded" iron process, which employs much higher percentages of silicon, and the effects of nickel and molybdenum in "Loded" irons were also remarked upon.

These latter irons can be cast centrifugally, and castings, known as Centricast "Loded," are being tried as cylinder liners on fleets of commercial vehicles, motor-boats, auxiliary engines, and land units, with encouraging results. Several sand-cast qualities of "Loded" irons are also proving interesting to various trades. There is evidence to show that these irons bring about a slowing-down of the wear rate of liners after the surface-forming period has passed. For example, on an extremely severe commercial vehicle service, liners of about 72 mm. bore showed a wear of 0·004 mm. to 0·005 mm. during the first 4,400 miles, but the following 4,400 miles showed no further wear of a measurable order. In speaking of cylinder wear, Mr. Young expressed the opinion (which controverts that held by some automobile engineers) that mechanical stresses, lack of unbroken oil film, erosion, flame action, gas penetration and debris, are more serious than corrosion in the majority of engines and services.

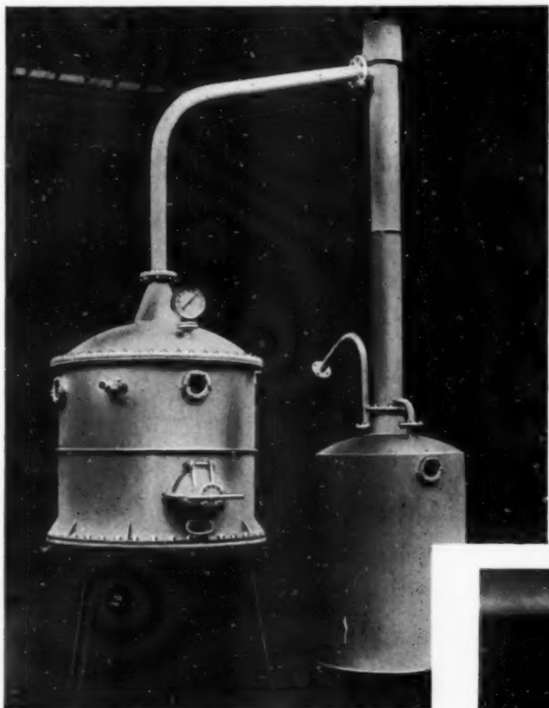
The author gave a list of the general properties of "Loded" irons as they are known in the qualities so far manufactured, and including others anticipated by various authorities. In conclusion, Mr. Young expressed the opinion that grey cast iron, "a material unexcelled for its past utility to engineering," is still in its infancy.

Corrosion and Heat-Resisting Steels

By Dr. W. H. Hatfield, F.R.S.

The advance in technology of corrosion- and heat-resisting steels is discussed under three headings: improved or new compositions, improvements in production, methods of manipulation and fabrication, and their increasing application. Progress in the development of these steels is emphasised.

IT is only about 25 years since stainless steel was first developed for the use of cutlery, but during this relatively short period the technology of corrosion and heat-resisting steels has advanced to a very remarkable degree, in fact, so much so that, both in this country and abroad these special steels are being used in increasingly large tonnages throughout the whole of industry. Further-



By courtesy of W. J. Fraser and Co., Ltd.

Vacuum Still and condenser in "Staybrite" steel.

more, the importance of these steels may be judged by the fact that a few years ago, in this country, two well-known Sheffield firms who had been pioneers in the development of these steels decided to pool their interests in the manufacture of corrosion- and heat-resisting steels, by the formation of a separate company—namely, Messrs. Firth-Vickers Stainless Steels, Ltd.,—and this company devotes its full resources solely to the production, development, and application of these special steels.

The advance in technology of these steels may be considered under several headings, viz.:—

1. The development of improved or new compositions.
2. Improvements in production, both as regards forms and sizes in which various steels are available, as well as in quality.
3. Increasing knowledge of the various methods of manipulation and fabrication of the steels, in all forms, into plant of every description.
4. The ever-widening application of these steels throughout all industries.

It may be useful to consider these four headings in some detail:—

Anyone who knows the numerous different types of corrosion- and heat-resisting steels now available, and, moreover, looked upon nowadays as standard steels, must be amazed at their development from the original 13% chromium stainless steel in a period of 25 years. Moreover, it is only during the last 15 years or so that the more widely used austenitic chromium-nickel corrosion-resisting steels, and the most useful heat-resisting steels have been introduced and developed to such a remarkable extent.

For the sake of reference, the following brief classification of the steels now available in this country may be helpful:—

Corrosion-Resisting Steels

(*a*) Plain chromium steels, such as 12 to 15% chromium, or 16 to 18% chromium, with varying carbon content.

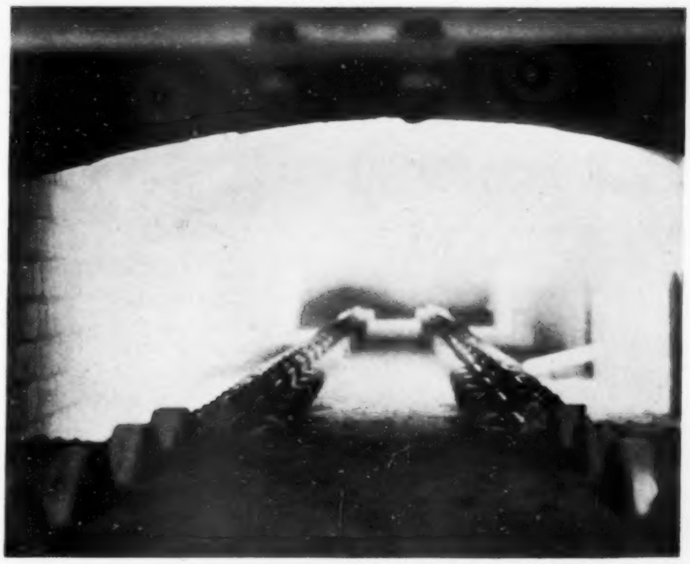
(*b*) High chromium—low nickel steel. (16 to 20% chromium, with 2% nickel).

(*c*) High chromium—high nickel austenitic steels, with additions of special elements, such as tungsten, titanium, and molybdenum. These are the "Staybrite" steel family.

Heat-Resisting Steels

(*a*) Plain chromium steels, such as 12 to 14% chromium, 16 to 18% chromium, 20% chromium, and 28 to 30% chromium.

(*b*) Silicon-chromium steels, such as 8% chromium—3% silicon.

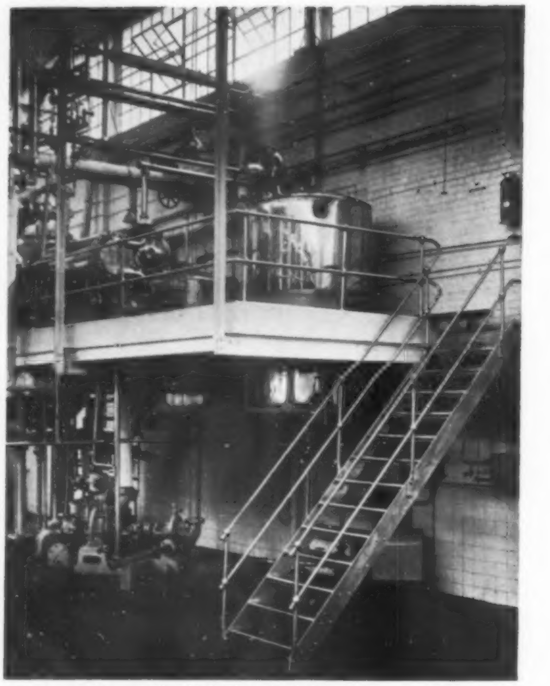


By courtesy of Messrs. Guest Keen & Baldwins Iron and Steel Co Ltd

Heat-resisting steel conveyer chain in sheet annealing furnaces.

(*c*) Austenitic high chromium—high nickel steels, with or without additions of tungsten, titanium, and other special elements.

(*d*) Higher nickel-chromium alloys, such as 60% nickel—20% chromium, 36% nickel—11% chromium, and 80% nickel—13% chromium.



By courtesy of Messrs Libby, McNeill, Libby, Ltd.

"Staybrite" steel milk condensing plant.

Taking the corrosion-resisting steels as classified above, it can be broadly stated that the order of corrosion-resistance increases from group (*a*) to group (*c*), and, at the same time, owing to the high ductility and general properties of the steels in group (*c*), these steels are available in a greater variety of forms and sizes than those in groups (*a*) and (*b*). Furthermore, the ease of manipulation and fabrication into plant render the steels in group (*c*) more readily applicable to all manner of equipment. On the other hand, for engineering purposes, where either high hardness or resistance to wear, or high mechanical strength are important, steels in groups (*a*) and (*b*) would come into consideration, since it is well known that steels in group (*c*) cannot be hardened by heat-treatment.

Referring now to the heat-resisting steels, it should be remembered that the term "resistance to heat" may be viewed from two angles—viz., the resistance of the steel to oxidation or scaling, and its resistance to "creep" under prolonged loading at elevated temperatures. With this in mind, and referring to the four main classifications of heat-resisting steels which I have indicated earlier, the steels in groups (*a*) and (*b*) are characterised by resistance to scaling under heat, and owe this property primarily to their content of chromium, assisted by high silicon content in the case of (*b*). Naturally, the amount of chromium present will determine the range of temperature for which the steels are suitable—for example, a steel containing 12 to 14% chromium will withstand oxidation very well up to, say, 750° C., whilst a 20% chromium steel is useful up to, say, 950-1,000° C., and a 30% chromium steel up to 1,150° C. On the other hand, the austenitic heat-resisting steels in groups (*c*) and (*d*) in addition to being resistant to oxidation also retain considerable strength and resistance to "creep" at elevated temperatures. It will be evident from the mere indication of the composition of the heat-resisting steels as classified above, that steels in groups (*c*) and (*d*) are more expensive than those in groups (*a*) and (*b*), but, on the other hand, as in the case of the corrosion-resisting steels, some of the austenitic heat-resisting steels are available in a greater variety of sizes and forms, and lend themselves more readily to plant fabrication.

For example, a 30% chromium steel cannot be produced in the form of solid drawn tubes, nor, in general, is it advisable to weld this steel, whereas a steel containing, say, 25% chromium and 20% of nickel can be produced as solid drawn tube, and is very suitable for fabrication by welding. Reverting to the question of "creep," a considerable amount of attention has been given to this during the past few years, and although much still requires to be done, for example, in co-ordinating and correlating various data by different workers, nevertheless, generally speaking, it is true to say that reliable "creep" data exists for all the standard heat-resisting steels. The interpretation of the creep data and the allowable working stresses deduced therefrom, will depend to a considerable extent upon the type of part in question and the duty it has to perform. For instance, the "safe stress" for the moving parts of rotary machines operating at elevated temperatures with fine clearances is very much lower than for such items as mechanical stoker links and chains, which permit a greater amount of deformation without interfering with the proper performance of their duty. Moreover, expensive precision machinery is probably designed for a life of many years, whilst on the other hand, for example, certain furnace parts may be easily replaced, permitting a higher stress with a possible consequent shorter life. It is therefore very desirable, in considering the use of a particular steel, to work at a high temperature under stress, to ascertain the maximum permissible rate of creep. To illustrate this, there is reason to believe that if a heat-resisting steel were exposed to a temperature of 800° C., such that a permissible rate of creep of 10^{-8} inch per inch per hour would allow of the application of a stress of 500 lb. per sq. in., a rate of 10^{-7} would permit a stress of 880 lb. per sq. in., 10^{-6} would permit 1,600 lb. per sq. in., and a rate of 10^{-5} would permit a stress of 3,400 lb. per sq. in. Further, since for a particular heat-resisting steel the "time-yield" figures (approximately equivalent to a rate of creep of a millionth of an inch per inch per hour), at temperatures of 800°, 900°, and 1,000° C., are respectively 1,200 lb., 280 lb., and 90 lb. per sq. in., it will be seen that care is needed in ascertaining the actual working temperature of the part, as an error of, say, 50° C. at such temperatures will result in a considerable difference in the allowable safe stress.

Having referred at some length to the development of improved or new compositions of both corrosion- and heat-resisting steels, giving briefly the various types now available, the next heading under which advance in the technology of these steels has been made is that of improvements in production, both as regards forms and sizes, as well as quality.

Improvements in Production

In this connection, during the past few years, very considerable amounts of capital expenditure have been undertaken in the extending and modernising of plant for the output of these steels, in the form of sheets, plates, strip, bars and rolled sections, castings, forgings, solid-drawn tubes, cold-drawn sections, wire, etc. The latest types of electric melting furnaces are installed for the melting and casting of the steels into ingot form, and all the working operations from the ingot to the finished bar or sheet are under constant technical control with a view to supplying a product of high quality, for it should be remembered that the properties and requirements demanded from these special steels are such that it is not possible nor desirable to relax any of the carefully controlled technique or stringent inspection to which they are submitted during manufacture, and on which their ultimate success in service to a large extent depends. In other words, increased production must not involve any depreciation in quality.

Manipulation and Fabrication

Coming now to the third heading under which advance in technology of these steels is being made—namely, in their manipulation and fabrication into plant—broadly speaking, it can be said that these special steels can be manipulated

and fabricated by practically every method which is used for ordinary steels and even for non-ferrous metals and alloys. There are naturally one or two exceptions to this (for example, these steels cannot be welded on the smiths' hearth), but, realising the special properties of the steels, compared with ordinary steels, it is perhaps a little surprising to the person without an intimate knowledge of them that they lend themselves so well to manipulation and fabrication by most of the recognised methods for other steels and alloys. In general terms, the chemical engineer need not look upon these steels as requiring an entirely new technique of fabrication, but rather should he view them as having been adjusted to meet existing and well-established methods. Every week, more and more plant fabricators and engineers are becoming acquainted with these steels, since all branches of industry are finding their use an advantage and even a necessity in certain directions. Forging, hot- and cold-pressing, forming, drawing, spinning, rivetting, soldering, welding, pickling, polishing and machining are all everyday operations of which a rapidly increasing number of firms are gaining experience in connection with corrosion- and heat-resisting steels. It is admitted, of course, that compared with the same operations on, say, mild steel, certain alterations have to be made and care exercised ; nevertheless, all these operations are now matters of everyday experience, and the manufacturers of the steels are always glad to give practical help and advice on such matters.

Increasing Fabrication

The fourth heading under which the advance in technology of corrosion- and heat-resisting steels may be considered is the increasing application of these steels throughout all industries. Going back about 25 years, the first serious commercial application for stainless steel was for cutlery, and whilst, up to about 15 years ago, the development of what became known as "stainless iron" provided a stainless steel with more ductility than the original cutlery quality, even so, it was not until the advent of the austenitic corrosion-resisting steels that, on account of their superior ductility and greater ease of manipulation, as well as increased corrosion-resistance, the various industries realised that here were steels which they could exploit to the full. It is no exaggeration to say that corrosion and heat-resisting steels have found their way into all industry, and whilst their worth is being taken advantage of by responsible Government Departments in the construction of aircraft, manufacture of explosives, numerous parts of Naval vessels, and ordnance, in fact by all departments concerned with the Defence Programme, at the same time these steels are being used in increasing quantities in ordinary industry and business for such diverse uses as automobile parts and fittings, architectural and decorative work, domestic utensils and fittings, chemical industry, brewery, dairy and food industries, glass, paper-making, refrigeration, and textile industries, hydraulic, electrical, civil and marine engineering, and many other branches of industry too numerous to mention.

Aeroplane Propeller Blade Life

The results of tests on two aeroplane propeller blades, which are briefly described, indicate that an aluminium forging of the composition given, if properly heat-treated is not damaged by over stress.

THE importance of the life of the propeller blades of an aeroplane cannot be too strongly emphasised, as the failure of a propeller generally involves a forced landing, which may lead to further damage to the plane or the engine. An aeroplane propeller blade is a tapered airfoil section which is subjected to combined stresses due to centrifugal, bending, and torsional loads, the magnitude of which can only be calculated approximately. There is also the factor that the properties of the precipitation hardened aluminium alloys used for aeroplane blades change with age and that vibrations may accelerate this change. Failures of such blades have been comparatively rare since an intensive study has shown that they are due to repeated applications of stress rather than to impact or suddenly applied load, and to stress raisers.

As no convincing evidence has been produced which shows that the mechanical properties of the material in a propeller blade are affected by service, although many tests have been conducted on used blades, tests recently completed at Wright Field, U.S.A., by J. B. Johnston and T. T. Oberg[1] on two blades manufactured from the same alloy and representative of modern practice, are of interest. One of these blades was flown on an experimental aeroplane and had 21 hours' service, whereas the other was removed from a commercial air liner after 4,233 hours' flying time.

The blades, which both contained approximately 4·3% copper, 0·5% iron, 0·75% manganese, and 0·90% silicon, were manufactured by a process of rolling and forging, followed by solution heat-treatment, and ageing at elevated temperatures. The test-pieces used to determine the mechanical properties were taken from the section of the blades in which the stresses were equal to or above the average stress in other parts of the blades. There was a difference in grain size and distribution in the two blades, but this had no apparent effect on the mechanical properties. The average mechanical properties of the two blades tested longitudinally were as follows :—

Hours' Service	21	..	4,233
Tensile Strength, tons per sq. in.	26·0	..	24·7
Yield-point (Set 0·002), tons per sq. in.	17·2	..	17·1
Prop. Limit (Set 0·0001), tons per sq. in.	13·3	..	14·4
Elongation, 4D %	18·2	..	16·0
Reduction of Area, %	29·8	..	27·0
Brinell Hardness	116	..	115
Fatigue Limit Rotating Beam, ton per sq. in.	4·46	..	5·35
Charpy, Impact, notched, ft.-lb.	9·93	..	9·34
Charpy Impact, no notch, ft.-lb.	96·13	..	95·95

These data indicate that an aluminium alloy forging of the composition dealt with and properly heat-treated is not damaged by over-stress. The endurance properties of the blade with the larger service is better than those of the blade which had little service, and the fatigue curves from both the blades fall within the area which has been found to represent the fatigue characteristics of the alloy. High-tension velocity impact tests were also determined, but could not be interpreted on account of the lack of data on aluminium alloys for such tests.

In general, propeller blade failures have, as already stated, been comparatively rare since investigations have shown that such were due to repeated applications of stress caused by stress raisers, such as abrupt changes of section between shank and blade, galling between propeller hub and shank of blade, surface damage from stones or other obstacles, and nodes of high stresses due to running in the range of the critical frequency of the blade. Stress raisers are eliminated by care and experience in design and by avoiding flying for any appreciable time at the critical speeds. Where fatigue cracks have started they can be detected by a light etching with an alkaline solution, and unless a crack has formed, it may be assumed that the metal has not been damaged.

[1] *Metals and Alloys*, 1938. Vol. 9, No. 10, pp. 259–262.

Industrial Management and Production Control

Part III.—The Position of the Stores in the Organisation and Layout of Works

By F. L. Meyenberg

The part played by the stores with respect to the organisation and layout of a works is discussed. It is considered that the stores manager and production manager should hold parallel positions, so that negotiations can be conducted on equal terms. The flow of material carried in the stores is discussed, and brief reference made to control. Considering the question of the layout of stores, the author deals with both centralisation and decentralisation.

Organisation

IN the introduction to these articles industrial works were likened to a body of organic structure, and it is obvious that the organisation, to fit accurately to this body, can never be "ready made"—it must be "made to measure." Nevertheless, for the purpose of these articles, it is necessary to take a certain organisation as a basis from which we can build up our conclusions, but the reader will appreciate that the example chosen is only one of the numerous possibilities.

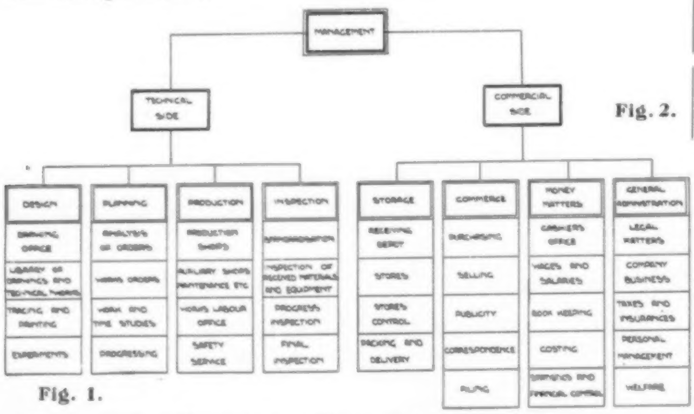


Fig. 1.

The example is illustrated by Fig. 1, which shows the two main sections of an organisation—the technical and commercial sections—with both of which the administration is actively connected.* In this case the stores belong to the commercial side, but it should be pointed out that this is not a necessity. In the administration of the stores so many technical points arise which are connected with the commercial side, that the stores, in the experience of the writer, can be managed just as well by the technical side. This is another instance where attention may be drawn to the principle that the characteristics of the persons concerned should be the main factor in determining the organisation, and not the organisation impressed on the persons.

For economical reasons it is necessary to emphasise that the stores should be independent of production proper. To a certain extent the stores control production, as far as the economical use of raw material, the delivery of finished goods, etc., are concerned, and the stores manager and the production manager should have parallel positions, as indicated in Fig. 1. Too often is the position of this point of view neglected by estimating stores managers as equal to those of the individual departmental managers working under the production manager. No contradiction is implied to the fact that the stores are bound to work in close co-operation with production, to which they have the same relationship as the supplier and the customer; in either case the best results will be obtained if the negotiations are conducted on equal terms.

Copies 1 & 2

Fig. 2.

It will be of interest to consider in detail how the stores are connected with other departments of the works. For this purpose it will be convenient to follow the flow of the material carried in the stores, and the clerical work which must be done in order that a complete report on this flow is available.

Material Issued from Stores

All material from outside sources is received at the receiving depot, either actually, when the nature of the material allows, or for booking purposes only, when the bulkiness or the nature of the material (ore, scrap, etc.) forbids intermediate storage in the receiving depot.

Copies 3 & 4

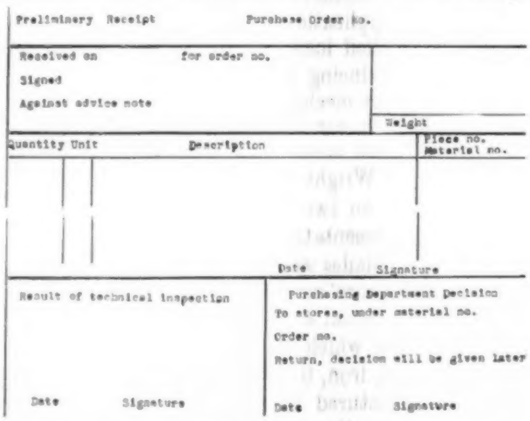


Fig. 3.

In the latter case, precautions must be taken to prevent the material being used before permission is expressly given, according to the organisation to be described. This is an important point which is often neglected. It must be admitted that this instruction is not always easy to carry out, but disregarding this important instruction may

* This example is similar to one given in a book recently published by Macdonald and Evans, London: "The New Management." By H. T. Hildage, T. G. Marple, and F. L. Meyenberg. (See METALLURGIA, June, 1938.)

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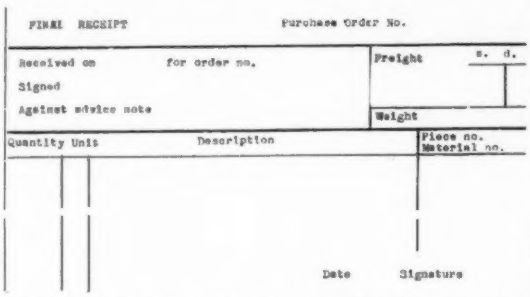

FINAL RECEIPT Purchase Order No.

Received on for order no. Freight s. d.

Signed

Against advice note Weight

Quantity	Unit	Description	Piece no. Material no.

Date Signature

Fig. 4

endanger the success of any objection raised to the acceptance of the material received.

In the office of the receiving depot seven copies of the receipt are made, using suitable printed forms, according to Figs. 2, 3, and 4. They are so arranged that the particulars on all copies are produced on a typewriter at the same time as the original is made. As may be seen, copies 1 and 2, on the one hand, and copies 3 and 4, on the other hand, are each called " preliminary receipt," copies 5, 6, and 7, " definite receipt." The differences between printed forms will be explained subsequently by their use in the various departments. The course of the copies is illustrated by Fig. 5.

Copy 1 (Fig. 2) is sent to the purchasing department for quick information, in order to prevent unnecessary correspondence with the supplier. Later, it is sent together with the supplier's invoice to the book-keeping department, and then returned to the purchasing department for filing. Copy 2 (Fig. 2) is sent to stores control for the quick information of the ordering department. Copies 3 and 4 (Fig. 3) are sent to the technical inspection department, which retains copy 3 for its files and sends copy 4 to the purchasing department, after having made the necessary tests and entered the results on this copy. The purchasing department decides whether the material can be accepted, makes this decision on copy 4, and returns it to the receiving depot. Here copies 4 and 5 are fastened together and sent to the purchasing department for comparison with the invoice of the supplier. Copies 1, 4, and 5 and the invoice are then sent to the book-keeping department, which returns the receipts 1, 4, and 5 to the files of the purchasing department. Copy 6 is sent with a copy of the invoice to stores control, copy 7 to the stores themselves.

It must be admitted that this organisation seems rather complicated at first glance; and the writer is the last to recommend it for every possible instance, but the reader can be assured that it has proved effective in various and very different industrial works, that it entails comparatively small clerical work, and presents, simultaneously, sufficient safety against carelessness and fraud. Special attention may be drawn to the fact that the receiving department must write down the receipt according to the actual material, as no advice note or supplier's invoice is at hand when the material arrives; thus it is impossible to " copy " the supplier's invoice and regard it as a receipt, as lazy receivers of the material are sometimes inclined to do. Another point of view worth mentioning is that no further co-operation of the supplier is expected, as for instance the sending of the invoice in duplicate. Experience has shown that any organisation which seeks the special co-operation of an outside firm is, to a certain extent, unreliable.

Finally, it may be added that *returns* of any kind are treated in the same way as new material; in these instances the intermediate storage in the receiving depot is very important, and, if possible, this practice should be adhered to.

Material Issued from Stores

As already explained in the second article, in requisitioning material from the stores, there is a distinction between material in stock. Part of the stock can and should be reserved for orders already received, but on which work has not begun; thus the material in the stores may comprise " actual " stock and " available " stock and may require to be separated in the stores book-keeping. On the other hand, however, such a separation may be superfluous or even absurd. The former will always be " direct " material, the latter either " direct " or " indirect " material. Both kinds of material are demanded from the stores by requisition slips of the same printed form, but of different colour. Requisition slips for direct material are generally made out by the planning department, those for indirect material by the consuming section; an original and one copy are provided, each having the same current number, so that all slips are easily traced and controlled.

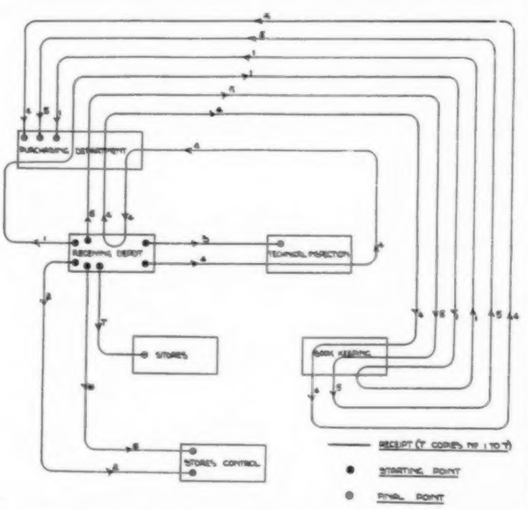


Fig. 5.—Showing the course of the various forms.

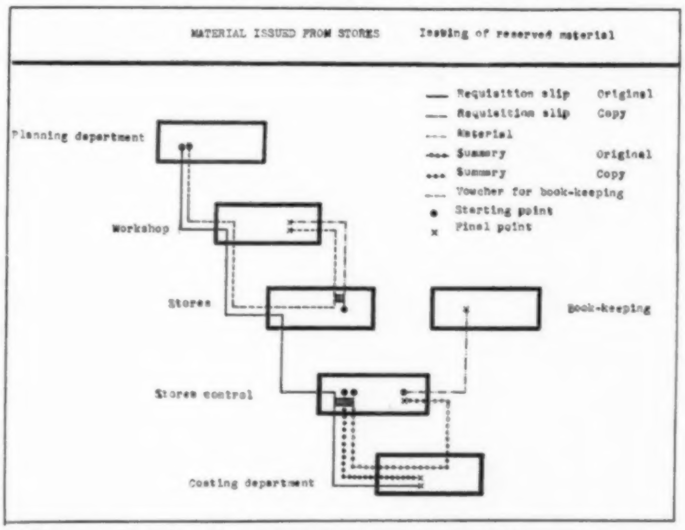


Fig. 6.—Showing the course of materials issued from the stores.

The course of the material issued from the stores, and the clerical work connected with it, is illustrated as example by Fig. 6 for " reserved material "—i.e., where it is decided to distinguish the material by " actual " and " available " stock. The scheme for " not reserved " material can easily be determined from Fig. 6.

The planning department makes out the requisition slips and sends the original and the copy together to the workshop, which in turn forwards both to the stores. From the stores the copy of the requisition slip travels, together with the material in question, to the workshop, while the original is sent to stores control. In the stores control all necessary details are entered into a card indexing system, which can be regarded as the key to the information about each material issued from the stores, and must, therefore, be very carefully kept. This point will be discussed later.

After the evaluation of the issued material and entry of the value on the requisition slip as well as in the card index, a summary is prepared and made out in duplicate. This can consist of a daily or a weekly summary, according to the number of the issue items, and the originals of the requisition slips with both copies of the summary then travel to the costing department, where they are examined, mistakes corrected, and failures rectified. The current numbers of the requisition slips provide a guide for the latter purpose.

When the copy of the summary is acknowledged as correct, it is returned as a receipt to the stores control and a short voucher informs the book-keeping department of the necessary figures to be taken from the summary. Thus, the book-keeping department receives daily or weekly figures for entering into the accounts, instead of figures for each detail, but the auditors can easily trace back the origin and composition of these figures to the single requisition slips, where they consider this to be necessary.

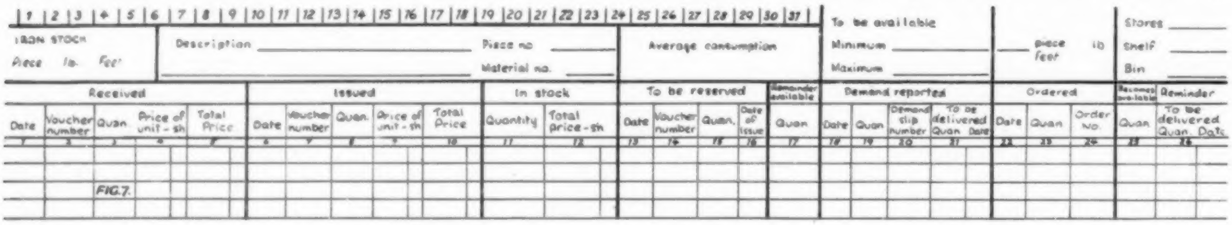


FIG. 7.

The requisition slips are collected, according to the order numbers, in the costing department, so that the consumption of the material can be determined for each order separately. This does not mean that the determination should be made for all orders; on the contrary, in many cases it has been proved that a complete calculation of all finished orders is unnecessary, as the advantage gained does not compensate for the amount of clerical work involved, but the costing department should be in a position to collect easily the costs of any order which the management may select for any special reason.

The Stores Control

A few remarks may be added about the work of the stores control, or rather its main tool—the stores card index. How it works may be gathered from Fig. 7, which shows only the head of the cards and scarcely needs a detailed explanation. It gives *as an example* the printed form of a card, which may be used for "reserved" material and would satisfy all demands which can be put to such a *document*. For example: one card is used for the type of material concerned, and the sum of all cards make a continuous inventory of the whole material existing in the works if—and this is essential—the cards are used and filled in properly. That is the important and difficult duty of all concerned with stores control, and the superintendent and his assistants must look after the correct working of this apparatus incessantly; for, as mentioned in our second article, mistakes too easily creep into these details, which, though small in themselves, may add up to amounts which make illusory the necessary survey, without which the management cannot lead the undertaking efficiently.

The foregoing explanations may be sufficient to convey a right impression of the position occupied by the stores in the organisation of the works. It will be appreciated that the explanations are not by any means exhaustive; what is hoped, however, is that these examples show the spirit in which these matters should be approached and dealt with. No attempt has been made to discuss the various mechanical auxiliaries, which, in these departments, facilitate the detail work that must be done in any case.

Lay-out

To discuss the stores as part of the lay-out of the works in a general way presents many limitations, since less can be mentioned than can be considered to be generally correct. It is proposed, therefore, to confine the discussion to the problem of centralisation or decentralisation of the stores.

It is obvious, from an administrative point of view, that the centralisation of the stores has great advantages, and therefore I have generally found an inclination towards this form. It must, however, be considered that, especially in metallurgical works where mostly large areas are covered, centralised stores easily increase the transport costs to an inadmissible amount. It is often difficult to find out whether this point is actually reached, because the determination of the actual losses by excess of transport is not an easy task and generally includes a mere estimation of some costs in addition to those which can be calculated. When looking for a suitable compromise, it should always be considered that administration is a service the demands of which must be secondary to those of the main work, especially if the latter is connected with such high costs as transport generally involves.

When the transport costs from a central store are likely to be excessive, two or more stores for the same material may be located in various parts of the works, and a new and difficult task of stores control arises. It is necessary to assign the right proportion of material to each individual store, to equalise stock, when issues from one store have been excessive, to consider all stores together when ordering new material, etc. The usual method of maintaining balance between the various stores is to use an individual card for each store and a main or summary card for all stores together; this certainly involves additional clerical work, and difficult clerical work too, but I only know of rare cases where it could be avoided with advantage.

In any case, it is important to guard against measures of distribution which allocate weekly or even monthly consumption of certain material to the foremen—i.e., building up "foremen stores," which have to be made good according to the quantities issued to the shops. Although, at first glance, this idea seems to be very promising, it cannot be too strongly pointed out that in practice the method is bad. The control of these numerous small stores becomes so difficult, that often it is entirely omitted and the necessary survey is lost. The writer could tell from his experience convincing examples, where material of a value amounting to hundreds and even thousands of pounds had disappeared from the books, and was found only after many months; material which was badly needed in other parts of the works.

He who believes that such or similar conditions are impossible in his own works may be congratulated wholeheartedly, but the writer, as a result of his many experiences of industrial practice, is usually somewhat sceptical of the accuracy of such statements.

Correction of Brasses for Zinc Loss

In a heat of brass the addition of copper or zinc is often necessary or advisable to effect adjustments of composition in a melt. To assist the practical foundryman in determining accurately the amount to be added Foundry Services, Ltd., have produced a very useful chart, scientifically known as a "Nomograph," which gives the information required for corrections in brass compositions. This chart, which has been developed by Mr. G. T. Salinger, gives full information on its use, and copies are available on application to Foundry Services, Ltd., 285, Long Acre, Nechells, Birmingham.

World Capacity for Aluminium Production

By Robert J. Anderson, D.Sc.

World capacity for aluminium production has been notably enlarged in the last decade. The present stage of aluminium development is of great interest, and in this article the situation in respect of world capacity and its distribution among countries is examined. Both minor and major producing countries are considered, as well as non-producing countries, and a comparison made with the development of other non-ferrous base metals.

MUCH interest has been attracted in non-ferrous metal circles to the substantial rise in world output of primary aluminium during recent years. In 1936 total output was about 30% greater than in 1929, while in 1937 it was nearly 74% more. The increase of output for 1937 over 1936 was approximately 34%. These advances are more striking when comparison is made with the variations in outputs of other non-ferrous base metals for the same years. Aluminium stood relatively far ahead in all cases with the sole exception that its percentage increase was almost the same as that of copper in 1937 as against 1936.

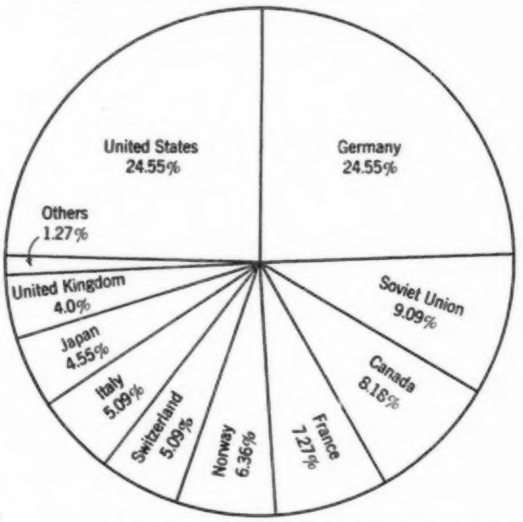


Fig. 1.—Distribution of capacity for producing primary aluminium in 1937.

World capacity for aluminium production has been notably enlarged within the last decade. New works or additions to old ones have been built by major companies in the principal industrial countries. Moreover, since 1930, aluminium production has been taken up for the first time in five countries. It is understood, of course, that the capacity for manufacturing alumina and also carbon electrodes has likewise been increased more or less correspondingly. Furthermore, the supply of electric power for the aluminium industry has had to be considerably augmented.

At the present stage of aluminium development the situation in respect of world capacity and its distribution among countries may be aptly examined. In this connection various plans for increasing output greatly on the near term enjoin special remark. On account of the importance of aluminium for military purposes, the whole matter is of particular interest at this time, since an European war seems contingent. Then, too, it is worth while to consider the effects of recent tendencies on the position of countries which produce aluminium chiefly for export.

As is well known, the possible annual output of an aluminium works depends upon not only the number and size of reduction cells, but also the amount of electricity available on the average during a year. The operation of a works may be restricted or stopped at times owing to lack of water for generating hydro-electric power. In the present discussion, capacity is considered to be the quantity of metal which can be produced per annum, provided that the power supply is sufficient. Of course, output is also affected by some other factors.

The figures of annual capacity given here are mostly estimates based on information obtained from various sources. In 1929, total world capacity for the production of primary aluminium was about 300,000 metric tons. In 1937 it was about 550,000 metric tons. Fig. 1 represents the approximate distribution of capacity, expressed in percentages of the total, as among countries for the latter year (cf. Table 1). In most cases the decimals, at least in the second place, are of no significance.

By present or current capacity is meant the nominal average capacity for output as of 1937. The unit of weight used throughout is the metric ton.

TABLE I.

WORLD CAPACITY FOR THE PRODUCTION OF PRIMARY ALUMINIUM.
In metric tons, thousands omitted.

Country.	Output, 1937 (*a*).	Capacity.		
		Present (1937).	% of Total.	To be Installed (*e*).
Australia	—	—	—	2
British India	—	—	—	5
Canada	42·6	45	0·18	35
France	34·5	40	7·27	5
Germany (*b*)	131·6	135	24·55	85
Holland	—	—	—	3
Hungary	1·2	2	0·36	5
Italy	22·9	28	5·09	20
Japan	10·5	25	4·55	20
Jugoslavia	0·3(*c*)	1	0·18(*c*)	5
Norway	23·0	35	6·36	5
Rumania	—	—	—	4
Soviet Union	45·0	50	9·09	40
Spain	(*d*)	2	0·36	—
Sweden	1·8	2	0·36	—
Switzerland	25·0	28	5·09	—
United Kingdom	19·4	22	4·0	10
United States	132·8	135	24·55	45
Totals	490·6	550	100	289

(*a*) As reported by the Metallgesellschaft A.-G.
(*b*) Including Austria.
(*c*) Including other European countries.
(*d*) Works closed in 1937.
(*e*) Estimated new capacity which may be ready for operation by 1940 or sooner.

Major Producing Countries

Ten countries now rank as major producers of primary aluminium. They are: Canada, France, Germany, Italy, Japan, Norway, the Soviet Union, Switzerland, the United Kingdom, and the United States. The current and prospec-

tive situations as to capacity in these countries are summarised below.

Total capacity of aluminium reduction works in Canada was 45,000 tons to 50,000 tons as of 1937. The former figure amounts to about 8·2% of world capacity. Additions projected for early completion are calculated to make possible an output in the country of approximately 80,000 tons annually. A programme for further enlargement of works over a period of years has also been planned. The consumption of aluminium in Canada is small, and most of the output has hitherto been exported. All ore is imported. At present the largest market for Canadian aluminium is within the British Empire, principally England.

The capacity for aluminium production in France has been given as upwards of 50,000 tons. Estimates of such order are evidently too high. It appears that the nominal total for all operative works is about 40,000 tons. This corresponds to nearly 7·3% of world capacity as estimated. French consumption of aluminium has lately been less than output, and a considerable quantity of metal was exported in 1937. Capacity of the country will probably not be increased much on the near term unless war breaks out. France is self-sufficient as to aluminium ore. It is the world's largest producer, and is also an important exporter of bauxite.

Remarkable developments have been made during recent years in the aluminium industry of Germany. Thus, the capacity of reduction works was tripled in the period 1934-1937. Further large additions are in the course of construction. Total capacity as of 1937 is estimated at 130,000 tons. This was raised to about 135,000 tons by the annexation of Austria with its two small works. The latter amount is approximately 24·5% of world capacity, and is practically the same as that of the United States. According to a late report, output of primary aluminium in Germany may reach about 180,000 tons in 1938. This would mean an increase of nearly 37% over the previous year. The great expansion of German capacity has been carried out under a special plan provided by the government. It now appears that total capacity may be raised to upwards of 220,000 tons annually by 1940 or sooner. Supplies of bauxite are wholly imported, since the home deposits are small and of poor quality.

Aluminium capacity of Italy is rated as 28,000 tons to 30,000 tons at the end of 1937. Output in that year was appreciably less. A capacity of 28,000 tons corresponds to about 5·1% of the world total. The Italian industry has expanded rapidly during late years, output in 1937 being more than three times that in 1929. New works have been built recently, and others are projected. A capacity of about 40,000 tons may be attained by the end of 1938. For the longer term the government has demanded that producers increase total capacity to 100,000 tons a year. Italy ranks among the foremost countries as to output of bauxite.

Industrial production of primary aluminium was begun in Japan only four years ago. Output has been increased to exceed 10,000 tons in 1937. The nominal capacity of all works has been given as 25,000 tons—about 4·5% of the world total—at the end of that year. It is claimed that full operation was impossible, due to lack of ore. As announced lately, capacity is being enlarged by the various producers with the view to providing a total of about 77,000 tons by 1941. The aim of a governmental plan is to reach a capacity of 120,000 tons within five years. Both domestic alunite and clay, as well as foreign bauxite, have been used as ore.

The total capacity of aluminium-reduction works in Norway is reckoned at approximately 35,000 tons, or nearly 6·4% of that estimated for the world. Output of this quantity has not been made. Norwegian consumption of aluminium does not amount to much, and nearly all the metal produced is exported. There seems to be no good reason for expecting any important enlargement of capacity in the near future. A small addition is, however, being made to one works. Aluminium ore is not mined in Norway. Alumina and bauxite are imported.

An outturn of primary aluminium by the Soviet Union was first reported for 1931 when the quantity was trifling. Since then the country has rapidly developed its industry. The output in 1937 was about 45,000 tons, and the capacity is estimated at 50,000 tons. This latter amount is approximately 9·1% of the world total. Works for an additional 25,000 tons may become operative shortly. As is known, semi-astronomical figures concerning proposed output of aluminium in the country have been frequently issued by Soviet sources. According to a recent announcement, it is intended to build three new works and to enlarge existing ones so as to have ready a total capacity of more than 200,000 tons by 1942. Since good deposits of bauxite were found a few years ago in the Soviet Union, its ore supply is now regarded as satisfactory.

The rated capacity of Switzerland for the production of primary aluminium is 28,000 tons. This corresponds to about 5.1% of the world total. One works was recently enlarged, but it does not seem likely that capacity will be increased much more in the immediate future. During the last decade Switzerland has lost rank among major producing countries as new works and additions elsewhere have come into operation. While home consumption is fairly substantial, almost 65% of Swiss output for the 10-year period 1928-1937 was exported. Bauxite is not found in Switzerland. Alumina is shipped to the reduction works from foreign ore-conversion plants of the producers.

Nominal capacity of aluminium works in the United Kingdom is estimated at 22,000 tons as of late 1937, or 4% of the total for the world. A programme of expansion has been prosecuted for some years and is now nearly completed. Capacity by the end of 1938 may be about 30,000 tons, but it is thought that output will not be above 25,000 tons. This capacity is considerably less than the indicated consumption—upwards of 47,000 tons—in 1937, when more than 32,000 tons were imported. Ore for the British industry comes from foreign sources.

The capacity of works for the production of primary aluminium in the United States is supposed to be approximately 135,000 tons annually. This is about 24·5% of the world total. Output is usually insufficient to cover domestic requirements, and a rather large amount of metal is ordinarily imported each year. The quantity drawn from abroad in 1937 exceeded 20,000 tons. In respect of primary aluminium, the United States has so far ranked first as to output and consumption for almost all years. But it may shortly be displaced by Germany in both. Also, up to now, the United States has been the largest producer and consumer of secondary aluminium, output in 1937 being nearly 57,000 tons. At the present time additions to American reduction works are being built. The new installations are expected to be ready for operation within two years, and the total capacity will then be about 180,000 tons. Both domestic and foreign (mostly South American) bauxite is used as ore in the United States.

Of the 10 major aluminium producing countries, at least three—Canada, Norway, and Switzerland—are to be denoted as surplus lands—that is, their output is considerably greater than home consumption. Two—the United Kingdom and the United States—are deficit countries—that is, substantial quantities of metal are imported in order to fulfil domestic requirements. In most cases output and consumption of the others is more or less in balance. The general situation just outlined is, of course, not to be regarded as permanent. In passing, it may be remarked that the consumption of aluminium in various countries can be much increased by substituting it for other metals on a strictly economic basis.

Minor Producing Countries

There are four minor aluminium producing countries—namely, Hungary, Jugoslavia, Spain, and Sweden. Their

combined capacity is only about 7,000 tons, or, say, 1¼% of the world total. The present position of these countries, as well as that presaged for the near term, is described briefly in the following paragraphs.

Primary aluminium was first produced in Hungary in 1935. Output is still insignificant, being only about 1,200 tons in 1937. Also, consumption is small. Capacity of the single works is rated at 2,000 tons. It is reported that this is soon to be doubled, and later to be increased to 6,000 tons. A project announced recently calls for the erection of another works with a capacity of 4,000 tons. Hungary is rich in bauxite resources and ranked second as to output in 1937. Most of the ore is exported to Germany.

The first aluminium works in Jugoslavia began to operate in 1937. Its capacity is given as 1,000 tons, and this is to be increased to 2,000 tons within a short time. Plans have also been made for building another works (capacity not stated). According to a late report, it is hoped to produce upwards of 5,000 tons annually, before long, with the view to supplying the requirements of the Little Entente. Present consumption of aluminium in Jugoslavia is trifling. The country is an important producer of bauxite.

There is a small aluminium works in Spain. It came into operation in 1928. Maximum output in any year since was about 1,300 tons. The capacity is somewhat less than 2,000 tons, which is ample to supply home demand. No output was made in 1937 for the works had previously to be closed on account of its proximity to a combat area of the civil war. Spanish bauxite deposits are small and of poor quality. Alumina has been imported for the reduction works.

Production of aluminium in Sweden was first begun in 1934 at a small works. The rated capacity is about 2,000 tons. Swedish consumption has been increasing during the last decade, and in 1937 approximately 2,900 tons of metal were imported. The indications are that a capacity of about 5,000 tons may soon be needed to supply the home requirements. So far, however, no reports concerning any additions have appeared. Bauxite is not found in Sweden. Alumina is imported.

Consumption and output are not much out of line in the case of Hungary, Jugoslavia, and Spain. Sweden is a deficit country.

Non-Producing Countries

As yet there is no primary aluminium industry in a number of countries where consumption is appreciable or else could be substantially increased. In most cases important financial interests in these countries or the governments wish to establish domestic reduction works. The desire to produce aluminium at home has been enhanced during late years as a result of changing politico-economic conditions throughout the world. Among other matters in this connection, the following may be mentioned: The growth of nationalism, the general drive toward self-sufficiency, the tendency to promote new industries in order to reduce imports and to relieve unemployment, and the necessity of controlling raw materials which are especially required for war.

Recent developments indicate that aluminium production may be expected to start soon in several countries, and will probably be undertaken later in some others. The current situation is outlined below.

According to report, an aluminium works with a capacity of about 2,000 tons is to be built in Australia. Total annual consumption of the country has been approaching this figure. The known deposits of bauxite in Australia are not good. Alumina will probably be imported at the outset.

Many proposals have been made concerning the establishment of an aluminium-reduction works in British India. Two projects, if not more, are in hand at the moment. One calls for the construction of a works with a capacity of 3,000 tons, while 8,000 tons is considered in the other. Annual imports of semi-manufactured aluminium products by British India reached a maximum of about 8,500 tons some years ago and latterly have approximated 3,000 tons. The country is rich in good bauxite, hydro-electric power sources, and coal, but its transport facilities are poor.

The question of producing aluminium in Holland has been studied lately by the government and also by several private interests. One company plans to erect a works with a capacity of 3,000 tons. This is more than enough to cover Dutch requirements at the present time. It has also been proposed to build a works in the Dutch East Indies. The exploitation of high-grade bauxite deposits was started recently in this colony, and the output was nearly 200,000 tons in 1937.

Plans have been made to produce aluminium in Rumania. Consumption of the country in 1937 was about 8,000 tons. One company has announced that it intends to construct a works with a capacity of 3,600 tons. According to recent report, a governmental project to produce the metal has been abandoned. Rumania contains important deposits of bauxite, but these have not been mined on a large scale since the World War.

Other countries where plans for aluminium production have been under consideration for some time include Belgium, China, Czechoslovakia, Greece, and Poland. It does not seem likely, however, that large works will soon be erected in these countries.

Summary of Capacity

Table I. gives the output of primary aluminium by countries in 1937, the estimated capacities for the same year, and the prospective additions which may be ready for operation by 1940 or earlier. The respective totals are also shown as well as the percentage distribution of present capacity (cf. Fig. 1).

As may be noted, the United States and Germany each accounted for about one-fourth of world capacity in 1937. A combined capacity amounting to almost half of the total was had by the other (eight) major producing countries—namely, Canada, France, Italy, Japan, Norway, the Soviet Union, Switzerland, and the United Kingdom. That of the four minor producing countries—Hungary, Jugoslavia, Spain, and Sweden—was about 1¼% of the world total. As already suggested, the decimals (if not some integers) of the percentages given in Table I are of little or no significance in most cases. They are merely the result of calculation.

Regarding new capacity which may come into operation within two years, as indicated in the last column of Table I., the figures are estimates based on reported intentions and data from various sources. Whether the total of nearly 290,000 tons and the quantities for the individual countries are attained will depend on the course of events. The prospective increase by 1940 certainly looks high. But it does seem probable that world capacity may reach 750,000 tons during the next few years.

Relation to Other Metals

The development of world aluminium output since the inception of the industry has been discussed at some length by the author.[1] Comparison was made there with other non-ferrous base metals. It is useful here to consider the relative situation with reference to the last year of record.

Table II gives the world outputs of aluminium, copper, lead, tin, and zinc in 1937 by weight and by volume, together with the totals as well as the individual percentages thereof. Up to now the maximum outputs of any year were recorded in 1937 for all the metals except lead. In 1929 world output of lead was a little more—58,900 tons, or about 3·5%—than in 1937. Figures for the maximum outputs so far attained are fairly well indicative of the nominal capacities for production. The former may be 10 to 15% less than the latter.

As emphasised in the work just cited, it is misleading to compare the output of a light and of a heavy metal on the

1 Anderson, R. J. "Long-term Growth of World Aluminium Output." METALLURGIA, vol. 18, No. 105 (July), 1938, pp. 87–90.

TABLE II.
WORLD OUTPUTS OF NON-FERROUS METALS, 1937.

Metal.	Weight Basis.		Volume Basis.	
	Metric Tons, Thousands. (a)	% of Total.	Cubic Meters, Thousands.	% of Total.
Aluminium ...	490·6	7·81	181·7	21·41
Copper	2,257·1	35·94	253·6	29·88
Lead.........	1,691·7	26·94	148·4	17·49
Tin	205·4	3·27	28·1	3·31
Zinc	1,635·2	26·04	237·0	27·92
Totals	6,280·0	100	848·8	100

(a) Primary (smelter) outputs as reported by the Metallgesellschaft A.-G.

basis of weight. The relation of outputs is more correctly conceived on the basis of volume. Table II shows the comparative positions of the several metals on both bases with reference to the combined output of all. The differences are striking. By way of example, the case of aluminium may be inspected. World output of the metal in 1937 was 490,600 tons, or about 7·8% of the total (6,280,000 tons) for the five metals. Correspondingly, the aluminium output was 181,700 cubic metres, or approximately 21·4% of the total (848,800 cubic metres) for the five metals.

The relative positions of the metals as given in Table II are illustrated graphically in Figs. 2 and 3. In the apportionment for Fig. 2 the percentages are of total output (all five metals) based on weight. For Fig. 3 the distribution is based on volume.

Examination of the statistical data discloses that the proportionate quantity of aluminium produced, as referred to the combined amount for the five metals, has increased rapidly over the course of late years. This is more evident when the volumes, rather than the weights, are considered.

Résumé and Conclusions

World output of primary aluminium and capacity for production have increased greatly during the last decade. Total capacity as of 1937 is estimated at 550,000 tons,

Fig. 2.—World output of non-ferrous metals ; percentages of the total, as based on weight.

while that in 1929 was about 300,000 tons. New capacity which may come into operation within the next few years is reckoned at 250,000 + tons. A large additional capacity has been planned for completion over a longer term.

Ten countries are ranked as major producers of primary aluminium—namely, the United States, Germany, the Soviet Union, Canada, France, Norway, Italy, Switzerland Japan, and the United Kingdom. There are four minor, producing countries—Sweden, Hungary, Jugoslavia, and Spain. It appears that aluminium production will be undertaken before long in Australia, British India, Holland, and Rumania.

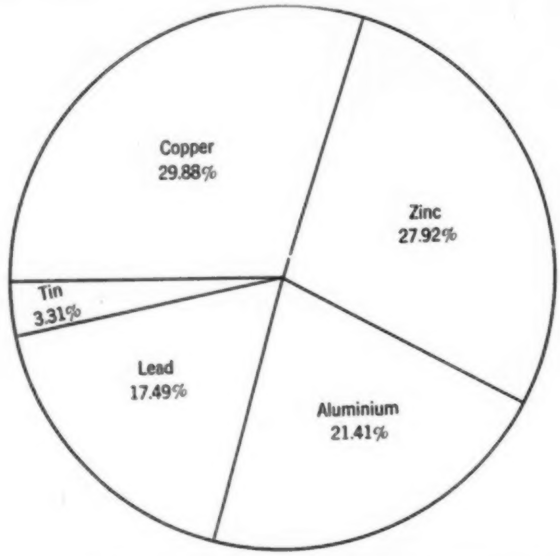


Fig. 3.—World output of non-ferrous metals ; percentages of the total, as based on volume.

Aluminium capacities of Canada and Norway are much greater than the home consumption, and works in these countries produce mostly for export. This applies to Switzerland in lesser degree. Capacities of the United States, Sweden, and the United Kingdom are insufficient to supply domestic requirements in years of active demand, and more or less metal is imported annually by these countries.

While aluminium output has increased very rapidly for the world as a whole during recent years, the relative gains made by the dictator countries are especially notable. Moreover, such countries have projected plans for greatly enlarging present capacity. As a consequence, shifts in the ranks of major producing and consuming areas are imminent. Apart from other reasons for developing their aluminium industries, one adequate incentive is that the war departments of autarchy nations place most reliance on aircraft. The several circumstances which have induced particular heed of aluminium in the totalitarian states have been discussed in another place.[2]

Attention has been directed to the relative position of the five metals—aluminium, copper, lead, tin, and zinc,—with reference to the total output of all five. It was also pointed out that the maxima of the outputs are not much below the respective capacities. On the basis of weight, the aluminium output was only about 7·8% of the total for the last year of record. But, on the basis of volume, it was about 24·1%. Finally, the indications are that the relative position of aluminium, in the respect stated, will continue to improve for an indeterminate period at the expense of copper, lead, tin, and zinc.

Catalogue SS. 11/3 has been received from the English Steel Corporation. This 16 pages and cover publication is printed in two colours, and describes "Vibrac" nickel-chrome-molybdenum alloy steel and its applications. Vibrac V 30 and V 45 steels are substantially the same in composition except for their carbon contents, V 30 having 0·27–0·35 carbon, and V 45 having 0·38–0·45 carbon, the latter finding application for larger parts. When dealing with parts of similar mass, V 30 after similar treatment will give rather lower tensile strength with greater ductility than V 45.

2 Anderson, R. J. "Economic Trends in the World Aluminium Industry." *The Mining Jour.*, vol. 202, No. 5377 (Sept. 10), 1938, pp. 853–5.

High Nickel Nickel-Chromium-Iron Alloys for Furnace Work

By J. O. Hitchcock, B.Sc.

Heat-treatment operations are usually carried out at temperatures which enable metals to be used in the design of suitable furnaces, and in this article the author describes some of the properties required in such metals, and suggests how they may be secured.

BEFORE it reaches the form in which it is ultimately required, a metal or alloy must be subjected to treatment of one kind or another, often involving the application of heat. It is, in fact, the facility with which metals can be softened and hardened at will by means of heat-treatment which enables them to be so well adapted to many engineering purposes.

Heat-treatment operations for steel include reheating for hot-working, normalising, annealing, hardening, tempering, and case-hardening, and many of these operations apply also to non-ferrous metals. The temperatures involved range from the boiling point of water to near the melting points of the metals themselves.

It will be clear that operations conducted over this wide range of temperatures will necessitate different types of heating apparatus or furnaces with a certain degree of versatility, and the materials used in their construction will have to satisfy somewhat diverse and stringent requirements.

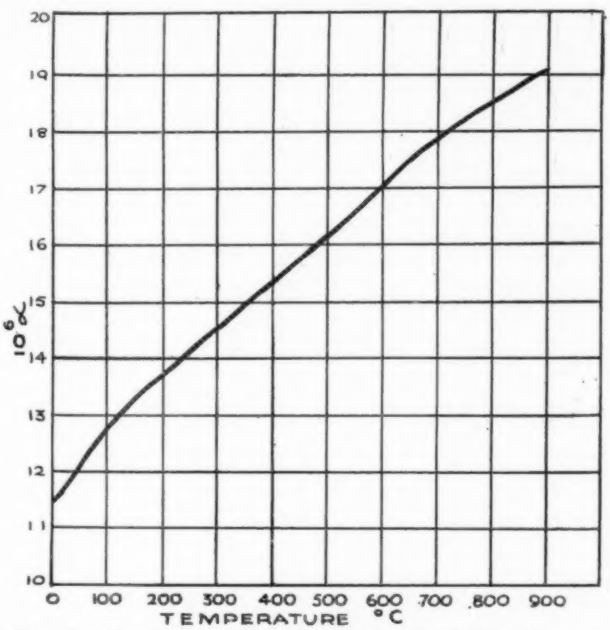
For furnaces operating at temperatures above about 1,200° C., it is necessary to use non-metallic refractory materials, unless water or other cooling systems are employed, because all otherwise suitable metals deteriorate rapidly at such temperatures. The use of these non-metallic materials gives rise to complicated problems of design and maintenance, and it is, therefore, fortunate that most heat-treatment operations are carried out at lower temperatures, and can thus be conducted in furnaces which make use of metals in their design. It is the purpose of this article to describe some of the properties required in such metals, and to offer some suggestions as to how these may be secured.

It may be stated briefly that some or all of the following characteristics will be of importance, according to the conditions to be encountered :—

1. Resistance to excessive scaling and chemical attack when in contact with oxidising and other gases at high temperatures.
2. Retention of strength and resistance to "creep" at elevated temperatures.
3. Toughness and freedom from brittleness, both initially and after service at high temperatures.
4. Stability of dimensions, particularly after repeated heating and cooling.
5. Availability in all engineering forms.

The introduction of electric heat-treatment furnaces tended to reduce the first question, that of scaling, to simple oxidation, but the more recent development of bright annealing processes has brought in its train the need for resistance to a variety of reducing gases, some of which have considerable destructive potentialities. Gas-, oil-, and coal-fired furnaces involve corrosive attack by the products of combustion, frequently of a sulphurous nature. Other potent causes of chemical attack include the compounds used in case-hardening at the ammoniacal atmosphere used in nitriding operations.

Strength and resistance to "creep" are self-evident requirements in the structural members exposed to heat. Toughness at both high and low temperatures is an additional necessity in parts, such as case-hardening boxes, which are likely to receive rough handling in use. Another advantage of a comparatively high strength is that this permits the use of thinner sections and a lower dead weight,



Fog. 1.—Thermal variation of the true expansion of — nickel-chromium-iron alloy.

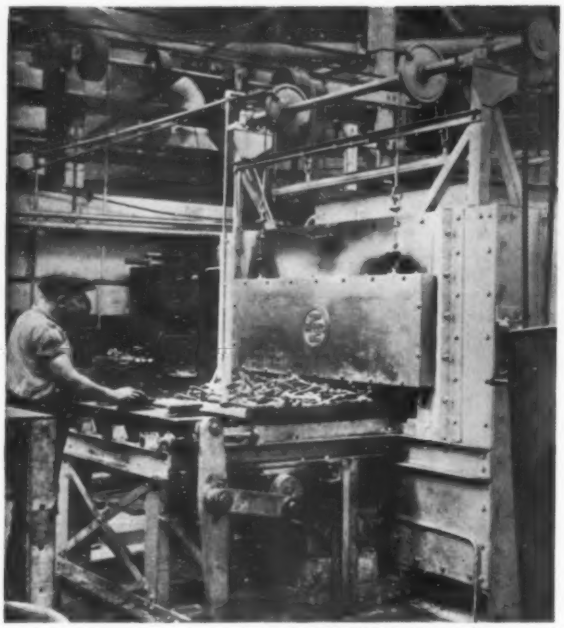
and results in fuel economies and more efficient transference of heat. Freedom from distortion and growth under the conditions of furnace work is another self-evident necessity.

Having noted the chief requirements in metals for heat-treatment furnace parts, it will now be of interest to compare them with the properties of those nickel-chromium-iron alloys which have been so widely adopted for this class of work.

Their composition usually lies within the following limits :—

	%
Nickel	60–80
Chromium	10–20
Tungsten	0– 4
Silicon	0– 2
Manganese	0– 2
Iron	Balance

Fig. 2.—Case-hardening boxes in "Cronite"—a nickel-chromium-iron alloy.



Courtesy of Birmingham Electric Furnaces, Ltd.

Fig. 3.—Pusher-type continuous electric furnace, for the heat-treatment of miscellaneous forgings, showing cast nickel-chromium-iron alloy work trays and carrier shoes.

Courtesy of Birmingham Electric Furnaces, Ltd.

Fig. 4.—Interior view of continuous electric furnace for the heat-treatment of high-tensile bolts, etc., showing cast-link belt conveyer in nickel-chromium-iron alloy.

carburized to a depth of ¼ in. after prolonged service.

So far as nitriding operations are concerned, it has been reported[3] that containers made from an alloy having 62% of nickel and 12·5% of chromium were practically unaffected after 1,500 hours' service. A further point of importance in this connection is that this type of alloy has no appreciable catalytic effect on the nitriding reactions, so that, taking both points into consideration, its cost is considered to be well warranted.

Controlled carburising or reducing atmospheres used in bright annealing and other heat-treatment operations have in some cases caused attack on metals at high temperatures,

TABLE A.

Condition.	Composition Percentages.			Room Temperature.				1,600° F. (872° C.) Short Time.*		
	Ni.	Cr.	Fe	Tensile Strength, Tons/Sq. In.	Yield Point, Tons/Sq. In.	Elongation, %.	Reduction of Area, %.	Tensile Strength, Tons/Sq. In.	Elongation %.	Reduction of Area, %.
As cast	65	15	Bal.	29	20	10	10	9	25	35

* Rate of Pull, 0·05 in.-hour.

TABLE B.

Alloy.				Time-Yield.					
Nickel, %.	Chromium, %.	Iron.	Manganese, %.	500°	600° Tons/Sq. In.	700°	800°	900° Lb./Sq. In.	1,000°
62	13	Bal.	1·4	15 approx	3¾	1½	1,500	300	100
78·55	13·44	Bal.	0·21	10	4	1¾	280	280	—
	0·25% carbon steel.			4	1	400 lb.			

Their resistance to scaling and chemical attack increases with the nickel and chromium content, though small percentages of silicon also have a beneficial effect, particularly in certain atmospheres. Hatfield[1] has shown that in an atmosphere typical of the combustion products of most normal fuels, the alloys containing a high percentage of nickel are practically unattacked at temperatures as high as 1,200° C. On the other hand, they are rather susceptible to the attack of gases containing a high percentage of sulphur, and under these conditions, particularly at elevated temperatures, it is preferable to employ alloys with a lower nickel content.

In contact with carburising compounds a high percentage of nickel has been shown[2] to have a beneficial effect in retarding the adsorption of carbon although instances have been met where the 65% nickel alloy has become

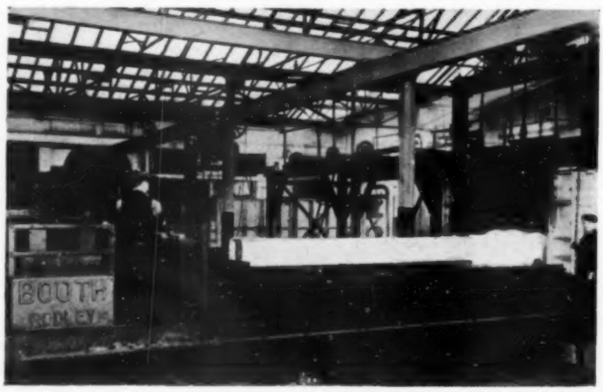
1 W. H. Hatfield. "Heat-Resisting Steels." *Jnl. Inst. Fuel*, 1938, vol. 11, pp. 245–304 : disc. pp. 440–50.

2 R. W. Roush and A. C. Dames. "A Study of Commercial Carburising Containers." *Trans. Amer. Soc. for Metals*, 1938, vol. 26, pp. 646–79 : disc. pp. 679–86.

3 J. W. Harsch and J. Muller. "Nitriding Containers. High Nickel Alloys Best." *Metal Progress*, Dec., 1931, vol. 20, pp. 41–4.

Fig. 5.—Large annealing muffle in nickel-chromium-iron alloy, mounted on a furnace charger.

Courtesy of the Cronite Foundry Co., Ltd.



Courtesy of Birmingham Electric Furnaces, Ltd.

Fig. 6.—Double-ended bogie hearth furnace for heat-treatment of heavy forgings, showing cast nickel-chromium-iron alloy work supports.

but it has been shown[4] that failures are comparatively rare, and it is thought that the nickel-chromium-iron alloys, with minor modifications for particular cases, can successfully meet requirements of this service. There are many installations, for instance, where these alloys operate satisfactorily in atmospheres ranging from cracked ammonia to practically burned coal gas and butane.

Laboratory tests have given further evidence of the freedom from chemical attack that these alloys exhibit in a variety of oxidising, reducing and special atmospheres. These tests show also that there is no doubt that their resistance is due to the character of the oxide film that forms on the surface. This oxide is adherent, and once formed offers a considerable degree of protection to the metal.

The mechanical properties of the wrought or cast nickel-chromium-iron alloys containing a high percentage of nickel present an interesting combination at both normal and elevated temperatures. Actual test results on the alloy as cast are shown in Table A,[2] and the ductility at 872° C. should be particularly noted. It is well known, of course, that under a constant stress at elevated temperatures a metal will fail at a much lower stress than when quickly pulled, so that short-time tests, though giving some idea of strength at elevated temperatures, cannot be used to give absolute figures.

A more accurate estimate, for design purposes, can be obtained from sustained or "creep" tests. Strength under sustained stress at high temperatures may be conveniently expressed[1] in terms of "time-yield" stress—that is, the stress required to produce "creep" at the rate of one millionth of an inch per inch per hour. Figures for the time-yield stress of two nickel-chromium-iron alloys and for a carbon steel are given in Table B.

The nickel-chromium-iron alloys have an austenitic type of structure, and do not undergo major transformations during heating and cooling from elevated temperatures; this fact, coupled with freedom from excessive grain growth at high temperatures, is an added assurance against embrittlement in service, and it is rare to find examples of fractured furnace parts in this type of alloy. It will readily be appreciated, of course, that the properties are greatly impaired by blowholes and similar imperfections, and, therefore, that sound castings are essential.

Stability of dimensions is assisted by the fact that within this type of alloy can be found a material with the lowest thermal expansion[5] of the common heat-resistant alloys, and also by the fact that the rate of increase of expansion is uniform over the range of temperatures employed (See Fig. 1). These characteristics minimise expansion and contraction strain during repeated heating and cooling. In addition to these points, the adherence of the protective oxide film is not impaired, as it would be if the expansion of the alloy were subject to sudden changes.

Approximate physical characteristics of the alloys are :—

Specific Heat	0·11 at 30° C.
Thermal Conductivity	0·033 at 30° C.
Specific Gravity	8·1–8·5
Electrical Resistivity	100–110 microhms/cm³ at 15° C.

Availability

The nickel-chromium-iron alloys can be produced in all the forms likely to be needed for furnace construction. They are most frequently used as castings, and while special foundry technique is necessary, no difficulty is experienced in producing quite intricate castings in some of the more complex compositions used for special purposes. Wrought forms are regularly produced, but naturally need considerably more power, etc., than ordinary materials in hot-working operations. The alloys can be welded by electric and gas methods, and many structures are being made in this way to-day.

Applications

Case-hardening boxes form one of the chief applications for which alloys of this type have proved most successful. It is interesting to note in this connection the improvements in design of box that have taken place in recent years to obtain more efficient heat distribution and economy of dead weight. Nickel-chromium-iron alloy boxes outlast those of steel many times, and give substantial savings in production costs. In addition, when their useful life is ended, the metal still has a good scrap value. Fig. 2 illustrates a batch of boxes prior to charging in an electric furnace.

In the construction of electric furnaces, nickel-chromium heat-resisting alloys are standard for such parts as element guards and supporting hooks, floor plates, woven wire conveyer belts, thermocouple tubes, and hearth-covering plates.

In gas-, oil-, and coal-fired furnaces, the alloys are used for hearth plates, dampers, roof supports, burner nozzles, baffles, and for many other structural members.

4. "Damage to Muffles by Controlled Atmospheres." *Metal Progress*, 1938, vol. 33, pp. 277–80.
5. P. Chevenard. "Recherches Experimentales sure les Alliages de Fer, de Nickel et de Chrome." *Trav. et Mem., Bureau International des Poids et Mesures.* 1927, vol. 17. Publ. Gauthier-Villars et Cie, Paris.

New Electrode for Depositing Machineable Alloy on Cast Iron

A NEW electrode, designated "Softweld," has recently been developed by the Lincoln Electric Co., for depositing a soft machineable alloy on cast iron. It is a heavily coated shielded arc electrode, having a size $\frac{5}{32}$ in. × 16 in. and polished at one end. The coating on this wire—a non-ferrous alloy—is designed to cause the weld metal to flow over and bond to the cast iron with a minimum of penetration or heating of the base metal. This electrode operates best with D.C. negative polarity, although A.C. may be used.

While a single layer deposit will be machineable in the weld metal, at least two layers should be deposited in order to obtain a soft fusion zone. The entire weld area may then be machined, sawn, drilled, and tapped without difficulty. Current should be just high enough to obtain the necessary bond. The arc should be fairly long—about $\frac{1}{8}$ in.—and the electrode should be moved slightly from side to side. An average of 90 amps. and 18 volts at the arc, generally, will be found satisfactory.

Localised heating is liable to crack cast iron and to avoid this care must be taken to keep the coating from getting too hot. The welding should be done intermittently, if necessary, and short beads—2 in. to 3 in.—are preferable. Each weld should be peened after depositing, the small amount of slag left on the bead may then be brushed off with a wire brush.

When correcting machining errors, or filling up sand holes or depressions, it is good practice to so prepare the work, by chipping, machining or grinding, that the final machined surface will allow for at least $\frac{1}{8}$ in. of weld metal. In those instances where a large or deep area is to be filled, or where a strength weld is required, it is more economical to use another type of electrode, like "Ferroweld," to within about $\frac{1}{8}$ in. of the machined surface, and then finish off with a couple of layers of "Softweld." These new electrodes are packed in 5-lb. containers, and are obtained from Lincoln Electric Co., Ltd., Welwyn Garden City, Herts.

* Bureau of Mines Report of Investigations, 3406.

Iron and Steel Institute

Additional Autumn Meeting at Cardiff

THE unfortunate cancellation of the visit of members of the Iron and Steel Institute to the United States of America, where arrangements had been made to hold the autumn meeting, seriously interfered with the technical programme. At the meeting subsequently arranged and held in London it was possible only to present for discussion a few of the papers specially prepared for the meeting in America. It was a happy thought, therefore, that additional autumn meetings should be held in various districts with the object of bringing some of these papers to the notice of members with a view to the promotion of discussion. The credit for this idea is believed to be due to Mr. J. S. Hollings, a Vice-President of the Institute,who presided at a meeting held in Cardiff on December 2, at which two papers were presented for discussion: "The Development of the Open-Hearth Steelmaking Processes in Recent Years in the United States of America," by Mr. L. F. Reinartz, and "American Soaking-Pit and Reheating-Furnace Design and Practice," by Messrs. F. M. Gillies and E. D. Martin.

In addition to the above meeting, a joint meeting of the Sheffield Society of Engineers and Metallurgists and members of the Iron and Steel Institute resident in the Sheffield district was held in Sheffield on December 6, when the paper by Professor J. H. Andrew and Dr. E. M. Trent, on "Quench Ageing of Steels," was presented by Dr. Trent; Dr. W. H. Hatfield, a Vice-President of the Iron and Steel Institute, presided. On the same date a further joint meeting was held in Scunthorpe; this was between the Lincolnshire Iron and Steel Institute and members of the Iron and Steel Institute resident in the Scunthorpe district. The subjects presented and discussed at this meeting comprised papers from the Lincolnshire district, presented to the Symposium on Steelmaking, organised by the Iron and Steel Institute in May last, and the paper by Mr. L. F. Reinartz on "The Development of the Open-Hearth Steelmaking Processes in Recent Years in the United States of America." Mr. C. J. Walsh, President of the Lincolnshire Iron and Steel Institute, and an honorary member of Council of the Iron and Steel Institute, was in the chair.

Arrangements have also been made to hold a joint meeting in Middlesbrough on December 19. This will be a meeting between the Cleveland Institution of Engineers and members of the Iron and Steel Institute resident in the Middlesbrough district, at which Mr. Arthur Dorman, Vice-President of the Iron and Steel Institute, will take the chair. The paper contributed to the Symposium on Steelmaking by Mr. James Winter, will be presented for discussion.

THE CARDIFF MEETING

The Lecture Theatre of the South Wales Institute of Engineers was reasonably full when Mr. Collings opened the meeting. After commenting on the fact that the papers to be presented were prepared for presentation in the United States of America, where the authors would have been able to present them and reply to discussion, he stated that although the members at this meeting were not in that happy position, they were fortunate in having Mr. P. M. Reinartz who had agreed to present his brother's paper and endeavour to reply to questions.

Development of the Open-Hearth Steel-Making Processes in recent years in the United States of America

By L. F. Reinartz.

The American steel industry owes a great part of its early rise to importance to the British tradition and perhaps especially to the Welsh pioneers in iron and steel in the States. Even when the author of our paper and your commentator began their steel-plant careers, the Welsh and English were still largely represented as iron-masters, melters, and furnace-helpers. It seems, therefore, especially fitting that a leading American metallurgist should have reported back to the source what progress has been made. It seems to me a particularly happy coincidence that this paper is to-night first presented in Wales.

I am conscious of a double honour this evening, first, in the kind invitation of this representative body of British steel-men to present this paper—and second, in thus being allowed to represent the author, my brother. I think you will pardon the personal reference when I say that it has been a distinct privilege to have spent some thirteen years in the steel-plant under the author's tutelage. When in his paper he calls attention to the necessity of constant close attention to detail and daily education of foremen and operatives, he himself has set a splendid example. Even in his present position he finds apparently unlimited time to study and discuss with his organisation from top to bottom what to another might seem trivial detail. He has pointed out that much unceasing watchfulness and conscientious study rather than inventive inspiration has been responsible for increased quality, higher efficiency, and reduced costs. Perhaps a word about the author's activity as Chairman of the Open-Hearth Steel Committee of the American Institute of Mining and Metallurgical Engineers would not be without interest to your own Open-Hearth Committee and to your Committee on the Heterogeneity of Steel Ingots, whose functions somewhat parallel the activities of the American body.

About 1915, when Mr. Reinartz first took the chair, any meeting of open-hearth men was largely a contest in lying which might have put Ananias to shame. Between competing steel-men, production and furnace records were claimed which doubtless their companies would have liked to see realised, but which actually have hardly been matched now after 20 years of progress. Of course, that could not have happened among British steel-men! Even in those days, Armco was committed to a high degree of specialisation in low-carbon steels and iron for sheet-rolling purposes, and, obviously, our performance records at that time were no match for medium- or high-carbon steel practice. Therefore, when Mr. Reinartz truthfully placed before the Open-Hearth Committee his proof, checker and furnace-life records, his figures on tons per furnace-hour and similar statistics, the other plant men were not abashed to present their own, relatively better, figures for comparison.

I feel sure, the active members of the American Open-Hearth Committee will to-day confirm that periodic exchange of vital open-hearth statistics has proved to be a stimulus to increased effectiveness, paying handsome dividends to all companies represented. The author has recorded the phenomenal growth of the American steel industry as a whole, ascribing this primarily to the rich ore deposits of the Minnesota and Michigan ranges. Perhaps a more commercial man would give equal importance to the rapid growth and continued existence of, doubtless, the world's largest and most receptive market for finished products in iron and steel. The author touches this commercial point when he shows that even the over-capacity developed during the Great War was entirely absorbed up to the year 1928.

The paper goes into some interesting detail concerning steel-plant lay-out and open-hearth furnace construction,

pointing out that the trend in America is to larger stationary units, with the cost of a modern 150-ton furnace, including its share of the auxiliary plant and buildings, being £160,000 sterling, and fixed charges of £60 sterling per day, whether operating or idle. The importance of avoiding delays in charging, melting, refining, and disposing of each heat is shown.

Concerning furnace design and construction, it will be seen that in the States there is close co-operation between the operator, the metallurgist, and the brick-mason. On the European Continent we have seen extremes of furnace maintenance at the expense of production and, therefore, a sluggish, slow-melting and refining, leading to detriment in quality.

The great amount of work and expense in controlled drafts, reversal by temperature, and combustion control, are discussed, and their principal value seen in the closer attention by engineers and operatives to these important quality and cost factors. Extensive insulation is generally practised, but extremes in this are being avoided as wasteful. Considerable virtue is ascribed to getting the engineer and furnace-man down into the open-hearth cellar, thus assuring careful maintenance of binding, brick-work, and valves. Heavy, rigid furnace bindings are praised. Preference for carefully sintered Austrian magnesite is shown, and careful repair after each heat and routine slagging-off of the bottoms is shown to be good practice. The relative merits of charging cycles are discussed. May I point out that all-scrap heats reported would hardly be recommendable in Britain, where the closer cycle of furnace to market-scrap to furnace has resulted in scrap contamination and suggests the necessity of dilution with virgin pig-metal. The necessity for careful dosage, not too much and not too little, in ore additions is recognised.

Great stress is laid on the importance of good pit-side practice. Pre-heating of ladles, drying of stopper-rods, and their careful adjustment in operation makes saving in money and improvements to surface quality. The bulk of rimming steel is top-poured. Economy of metal and operating cost has resulted from killed steel hot-top improvements. The importance of suitable ingot dimension and shape and the effect of mould and metal temperature and pouring speeds is covered. The suggestion that painted, galvanised, and especially detinned scrap be segregated for only ordinary grades of steel, may strike a responsive cord, especially in Britain.

Attention to close pig-metal analysis and temperature is recorded, with a nice adjustment of the lime-silica ratio to suit local materials and products.

The necessarily condensed report of slag control development covers years of conscientious research in laboratory and shop. The author stresses that, whatever type of slag and metal control may be practised, personnel training is of prime importance. The extension of quality improvements to rail, structural and plate steel, heretofore slightingly called " commodity grades," has led to better prices, but nevertheless to economies in weight and construction cost.

In foundry steel, the relative effect of aluminium and sulphur on ductility of steel castings is discussed, and the new quality demands placed on rimming steel ingots for continuous hot and cold strip-mill rolling, are shown. The importance of this phase of steel-making will be recognised because to-day 42 to 45% of all American ingots are being rolled through such continuous mills for many kinds of flat-rolled product. The necessity for tough-skinned ingots, free from cracking after stripping or in rolling, is evident.

The author's remarks both as to the importance of ingot dimension and shape and the growing use of sodium-fluoride to improve internal ingot structure, may be of interest to your Committee on Heterogeneity. The persistence of the acid open-hearth process for important forgings and armament requirements is shown, together with a typical heat-history.

The space given by the author to safety and accident prevention is hardly proportionate to the great amount of effort expended in this field by practically all American steel companies. Safety supervision has almost universally become a major staff function in steel plant management.

In conclusion, the author shows how thoroughly he has fallen under the ethical and romantic spell of steel-making, which seem to be the *sine qua non* for success in our interesting profession.

I must beg your indulgence during the discussion if some of the points brought out cannot be answered at once. For the past 10 years I have only had the opportunity of observing American steel practice during my short visits back to the States. However, I feel free to say that any questions which you may wish to raise, if they cannot be answered from the floor, will gladly be referred back to the author and his answer will be submitted in writing through the usual channels.

Messrs. R. P. Smith, Davies, Brooke, and several members contributed to the discussion, and all were agreed that this paper was probably the best yet presented to the Institute on open-hearth steel-making processes. Each commented on the admirable manner in which the paper had been presented and expressed their thanks to Mr. Edwards for undertaking this work and so contributing to the success of the meeting.

American Soaking-Pit and Reheating Furnace Design and Practice

By F. M. GILLIES AND E. D. MARTIN.
Presented by Mr. K. HEADLAM-MORLEY.

A transformation in American soaking-pit and reheating-furnace design and practice has come about in the last 10 years, which has not only made possible great savings in the specific operations of heating, but, through better quality of heating, has also influenced the economy of succeeding operations and greatly improved the quality of the product. Rolling-mill operators in America came only gradually to a realisation that the quality of heating influences the quality of steel both in subsequent rolling and as a finished product. The cost of poor quality of heating is demonstrated. Prevalent in America, wage payment based on the tonnage heated is a poor practice, while a characteristic deficiency is the designing of new mills with inadequate heating capacity.

Advances in fuels, regenerators and recuperators, tightness of the furnace, control systems, refractories and heat-resisting alloys which have been made apply to both the classes of industrial furnaces discussed. An historical background to the development of soaking-pit design leads to a more detailed description and discussion of four distinct types, together with statistics compiled by the authors to give a cross-section of present equipment and practice in America. The development of furnaces for reheating is presented from older types through the advent of recuperators and the appreciation of a fundamental conflict in design, to the necessity for zoning the furnace and heating the bottom of the steel. This is followed by a description of the main types of modern reheating furnaces, of which the trend is definitely towards the continuous type.

It is concluded that much of the development came from necessity, and the main cause has been the great progress in the manufacture of rolled products. The high competition among American steel manufacturers necessitated consideration of all elements that are involved in the production of the highest quality of product cheaply. The wide continuous-strip mill came to meet this situation, and because, according to experienced rolling mill men, the furnaces are of major importance in any rolling process, the challenge of these high-capacity units had to be met. This forced situation did not stop at reheating equipment in these mills, but a recognised necessity for higher quality of slabs called for better blooming-mill practice. Hundreds of thousands of dollars were being spent annually through-

out the United States for slab preparation, and this, too, demanded attention. The soaking pits of recent construction (approximately 150 were built in 1937) have done much to improve the quality of this product at their end of the rolling process.

The constantly increasing labour costs in America present another forcing factor. Added to this also, the increasing opposition to work that can be considered irksome by the residual labour forces of America has been a motivating influence for more mechanisation and extended study of ways to bring about a situation of less dependency on labour. To accomplish this, the American steel industry has spent no less than fifteen million dollars on new equipment, of the types described by the authors, since 1934. Undoubtedly this is a larger expenditure than has been made for such equipment during any previous period in its existence. All this has been done at a time when American industry is not certain where the future is to lead it. True, a good portion is in new capacity and in new methods, but it nevertheless proves that the transition which has occurred in soaking pits and other reheating furnaces is immensely valuable both in improved quality and in much-needed economy.

For these reasons it is believed that, while the American steel industry is passing through dark years at present, it will, when it emerges, utilise the developments described to a greater extent than at any time in its previous history.

THE SHEFFIELD MEETING

THIS meeting was held in the Metallurgical Club, Sheffield, with Dr. W. H. Hatfield, F.R.S., in the chair, who in calling upon Dr. Trent to present the paper on the quench-ageing of steel commented upon the importance of this contribution to knowledge on the subject. In the paper experiments are described on the age-hardening of a series of iron-nitrogen alloys of a fairly high degree of purity which have led to important conclusions. It is possible only to present a summary of the paper here.

The Quench-Ageing of Steel

By Professor J. H. ANDREW, D.Sc., and E. M. TRENT, M.Met., Ph.D.

Details are given of experiments carried out to determine the effect of carbon upon the rate and magnitude of ageing, as measured by increment in the Vickers hardness values—ageing being brought about by quenching the normalised steels from temperatures below the Ac_1 transformation point.

The effect of small additions of silicon, manganese, aluminium, and molybdenum have also been determined. The method adopted was to carburise pure iron in acetylene gas, along with pure iron to which the special elements had been added. The carburised bars were sectioned by cutting them at such an angle as to allow of a large number of hardness impressions to be taken between the carburised surface and the centre of the bar.

In nearly all cases, it was found that the maximum increment in hardness at 25° C. occurred in a zone corresponding to a carbon content of approximately 0.035%, after quenching from a temperature just below the Ac_1 point. This carbon content corresponds to that amount which is regarded as the limit of solubility of carbon in α-iron.

The addition of manganese up to 1·0% or of molybdenum up to 1·0% decreased the ageing; silicon up to 0·88% produced but small differences, whilst aluminium up to 0·47% brought about an increase in ageing as measured by hardness determinations.

Nitrogenised iron after quenching from certain temperatures gave a much greater increment in hardness as compared with iron-carbon alloys; further, nitro-martensite, unlike martensite in an iron-carbon alloy, showed considerable ageing at atmospheric temperature. The view is held that the increment in hardness produced in ageing is due to the strain in the lattice produced by carbide of iron or nitride of iron, prior to their precipitation from solid solution.

The effect of a Vickers diamond impression when made immediately after quenching for ageing and after quenching followed by fully ageing, is of considerable interest. In the former case, no effect upon the precipitation was produced, but in the latter the whole of the carbide or nitride immediately surrounding the impression was taken into solution. This clearly signifies that mechanical strain is in itself sufficient to bring about a re-solution of carbide or nitride, when such a strain is imposed at atmospheric temperature. Whether this is due to a temperature effect along the slip planes cannot as yet be stated, but further work is in progress relative to this problem.

The Influence of the Cooling Rate on the Transformations in Steel

EXPERIMENTS carried out by means of two different dilatometers are described by Franz Wever, Adolf Rose and Heinrich Lange,* one based on purely electric, the other on photo-electric principles, in order to determine the influence of small cooling rates on the transformations in steel.

It has been found by former investigations that the transformation temperatures of the equilibrium diagram hold good only for infinitely small speeds of the change of temperature, and that already very small cooling rates bring about a surprisingly large displacement to lower temperatures. This displacement takes place in three stages, clearly distinguished from each other, and each stage involves certain significant changes of properties.

As this problem has not only theoretical but also considerable practical importance, the attempt is made to find out by a more detailed investigation what sort of course the transition from equilibrium to the first undercooling stage takes in carbon steels as used in practice.

The investigated steels had carbon contents between 0·01% and 1·68%. By means of the first instrument, tests are made at heating speeds of 1°/second, and cooling rates of 0·04° to 40°/second. The results are given in overheating and undercooling diagrams. They show that both, overheating as well as undercooling of the A_1-transformation, are practically independent of the carbon content. The A_3-transformation is much more undercooled than the A_1-transformation. The share of the pre-eutectoid precipitation of ferrite in the total process of transformation of the hypo-eutectoid steels decreases therefore with increasing cooling rates, until only the A_1-point comes into question. The pre-eutectoid precipitation of cementite is already stopped by very small cooling rates. The A_1-transformation is much decreased by a very small cooling rate.

The second instrument is especially designed for the smallest investigated cooling rates. It records the change of temperature as well as that of length. For the latter purpose a photo-electric device is used which is practically devoid of inertia. By the change of the length of the test-piece two lattices are displaced against each other, a fact which influences a current of light proportionally. This current is measured photo-electrically and recorded by the instrument as directly dependent on the temperature. The apparatus operates with very small test-pieces and with extremely light pressure of the indicator arm. The investigations with this instrument referred to the hysteresis of the temperature of the A_1-transformation at various heating and cooling rates between 8° and 0·5°/minute, or 0·133° and 0·0083°/second—i.e., at rates which were generally much smaller than those used at the tests with the first instrument.

* "Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf," Vol. XX, No. 5.

Business Notes and News

Trade Recovery Optimism

There are signs that the pendulum is again preparing to swing in the direction of recovery, and with an international situation so troubled and uncertain as the present, even limited indications of improvement are doubly significant. One encouraging factor is the steady rise in the index of industrial activity in the United States. It is more than a revival of the stock and share markets and represents an industrial quickening which is bound to have repercussions on world trade.

The figures for British industrial activity, when due allowance is made for the time-lag, are also showing signs that the United Kingdom is beginning to benefit by an upward movement. Encouragement might also be drawn from the high level of retail trade, the daily sales of which had increased by about 2½% this year. And, on a longer view, there could be no doubt of our ability to withstand a trade setback to-day better than in the crisis year 1931. In the interval, effective steps have been taken to secure the home market, and generally the home market is more important than the export market; but there is every indication that the export market will benefit from improved trade.

Birmid Industries, Ltd.

The recent report of Birmid Industries, Ltd., shows that its subsidiary companies earned increased profits as compared with a year ago. The component companies are engaged in the production of aluminium and magnesium alloy castings, and in the rolling of sheet for use in the aeroplane, motor-car, and general engineering industries. One of the products of a subsidiary company, "Birmabright," is making considerable progress in its application to shipbuilding and marine engineering uses. This is an aluminium alloy which possesses remarkable resistance to atmospheric corrosion and is giving excellent service in marine applications, because of its resistance to sea-water corrosion. About 70 or 80 ships' lifeboats have now been made in this material, and the demand is increasing. In a subsequent issue, we shall deal with the properties of "Birmabright" and direct attention to some of its applications.

The output for the year of all the subsidiaries has been maintained, despite the recession in the motor-car industry and the consequent reduction in the amount consumed, since the loss has been more than compensated by a substantial increase in the aircraft and general engineering business.

Plea for Government Support of Shipping

That British ships should receive the full backing of Government departments was the opinion expressed by the Rt. Hon. Lord Essendon at the recent general meeting of the Prince Line, Ltd. He did not regret the standard of safety, of manning, or wages on which British ships are operated under present conditions, but shipowners did expect that at least they should have the same measure of support as their foreign competitors received. Although not desirous of using the occasion for submitting suggestions as to how the shipping industry can best be helped through the existing period of unremunerative freights and high shipbuilding costs, it is not without interest to recall that in somewhat similar circumstances, although in different degree and for different reasons, the United States Government have adopted the principle of a subsidy to their shipowners to cover the difference between operating costs under the American flag as compared with foreign flag tonnage, and a further subsidy to shipbuilders to cover the difference between American building costs and costs abroad. In this way the United States Government takes care of the difference between the standards of life established by their political economy and lower standards of other countries.

Ley's Foundries

Ley's Foundries and Engineering, Ltd., which comprise Ley's Malleable Castings Co. and the Ewart Chainbelt Co., has made good progress during its second year of operations. Foundry capacity has been increased and the firm claims to have the most efficient equipment for producing 600 tons of castings per week at an economical price. In addition to new melting and moulding plants, an annealing equipment of improved design has been installed which gives exceptionally close control of temperature and constitutes a valuable addition to the existing pulverised coal ovens and electric short-cycle annealing ovens.

The principal product is blackheart malleable iron castings, but there is an increasing demand for this company's "Lepuz" metal for a variety of applications, particularly brake drums for both passenger and commercial vehicles. The company is also regularly making castings in "Nihard" material, which has excellent abrasion-resisting qualities, and is especially suitable for parts subjected to severe wearing conditions.

Demand for the products of both operating concerns appears to be expanding. So far as the malleable castings are concerned, the business suffered its first check during the year after a long period of expansion, but apparently the contraction in normal trade was largely offset by armament orders, but the foundry is admirably placed to participate to the fullest extent in any continued recovery of trade, whether in executing orders for blackheart malleable castings or for various wear-resisting alloys.

New Bessemer Shop at Krivoi Rog

The building is being completed of a huge Bessemer shop at the Krivoi Rog Metallurgical Works The shop will be the largest and best equipped of its kind in the U.S.S.R. It wil have an output capacity of 1,700,000 tons of steel a year. Its daily output of high quality metal will be 5,200 tons. The whole of its plant has been manufactured in the Soviet Union.

Extension of Chesterfield Tube Works

An interesting ceremony took place on December 8, when the Rt. Hon. the Earl of Stanhope, K.G., D.S.O., M.C., First Lord of the Admiralty, officially opened the works extensions of the Chesterfield Tube Co., Ltd., by setting a large piercing press in operation on an 8-ton pre-heated steel ingot. The building housing the new plant installed comprises two parallel bays, one 660 ft. long, 100 ft. wide, and 60 ft. high, the other 615 ft. long, 50 ft. wide, and 33 ft. 6 in. high. Owing to the size and weight of the principal units of the plant, extensive excavations and foundations were necessary, reaching in some cases to a depth of 45 ft. below floor level.

The plant consists of a vertical, hydraulic, triple cylinder, billet-piercing press of a power to operate on a billet or ingot having a weight of 20 tons. Auxiliary hydraulic cylinders are fitted for moving the container from under the press and ejecting the pierced bloom. The press, which has a total weight of 850 tons, is capable of producing in one operation a hollow forging 9 ft. in length. The horizontal, hydraulic tube draw bench is also of the triple cylinder type, the maximum stroke being 40 ft., and hollow blooms of approximately 20 tons can be mandrel drawn. The draw bench has an overall length of 146 ft., and weighs over 500 tons.

The furnace equipment comprises a bogie tunnel furnace of the multi-pass regenerative type, with a temperature range up to 1,300° C., a soaking pit furnace of the multi-pass regenerative type, designed for a maximum working temperature of 1,300° C., and a recuperative tube reheating furnace. The furnaces are fired by gas, piped from the coke ovens of local collieries, and the annual gas consumption is estimated at three hundred million cubic feet.

The hydraulic equipment for the piercing press and the draw bench consists of three pumps, each driven by a 6,600 volt 3-phase synchronous motor of 600 h.p. The accumulator is of the air hydraulic type, comprising air and water receivers. The pumps are arranged to run continuously when the plant is working; electrically operated valves controlling the supply of pressure water to the accumulator according to the demand from the machines. With little exception, the plant and equipment is of British manufacture, and has been erected in co-operation with and to the design of the Loewy Engineering Co., Ltd., of London, the consulting engineers to the company.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100	0	0

ANTIMONY.

English		£71	0	0
Chinese		56	0	0
Crude		38	0	0

BRASS.

Solid Drawn Tubes	lb.	0	1	0
Brazed Tubes	,,	0	1	2
Rods Drawn	,,	0	0	9⅜
Wire	,,	0	0	8⅞
*Extruded Brass Bars	,,	0	0	5

COPPER.

Standard Cash		£43	7	6
Electrolytic		49	5	0
Best Selected		48	12	6
Tough		48	2	6
Sheets		81	2	6
Wire Bars		49	17	6
Ingot Bars		49	17	6
Solid Drawn Tubes	lb.	0	1	1
Brazed Tubes	,,	0	1	1

FERRO ALLOYS.

‡Tungsten Metal ° Powder, nominal	lb.	£0	4	9½
‡Ferro Tungsten ° nominal	,,	0	4	8
Ferro Molybdenum °				
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2-4% Carbon, scale 12/- per unit	ton	34	15	0
NOMINAL: 4-6% Carbon, scale 8/- per unit	,,	24	5	0
NOMINAL: 6-8 Carbon, scale 7/6 per unit	,,	24	0	0
NOMINAL: 8-10% Carbon, scale 7/6 per unit	,,	24	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon, scale 13/- per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/- per unit	,,	49	0	0
‡Manganese Metal 97-98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	5
§Ferro-Vanadium 25-50%	,,	0	14	0
§Spiegel, 18-20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	12	0	0
45/50% basis 45%, scale 5/- per unit	,,	12	10	0
70/80% basis 75%, scale 7/- per unit	,,	17	0	0
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn, basis 65% Mn	,,	15	15	0
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20-25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	5

FUELS.

Foundry Coke—				
S. Wales	—	2	0	0
Scotland	—	1	15	0
Durham	—	1	14	6
Furnace Coke—				
Scotland	—	1	10	0
S. Wales	—	1	7	6
Durham	—	1	7	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£65	0	0
*Commercial Ingots		48	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

MANUFACTURED IRON.

Scotland—				
Crown Bars		£13	10	0
N.E. Coast—				
Rivets		12	15	0
Best Bars		15	15	0
Common Bars		12	10	0
Lancashire—				
Crown Bars		13	10	0
Hoops		14	2	6
Midlands—				
Crown Bars		13	10	0
Marked Bars		15	15	0
Unmarked Bars			—	
Nut and Bolt Bars		11	15	0
Gas Strip		14	2	6
S. Yorks.—				
Best Bars		15	15	0
Hoops		14	2	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	0	11
*Cored Bars	,,	0	1	1
†Strip	,,	0	0	11¼
†Sheet to 10 W.G.	,,	0	0	11¾
†Wire	,,	0	1	1⅜
†Rods	,,	0	1	1½
†Tubes	,,	0	1	6¾
†Castings	,,	0	1	3

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £32 above English Ingots.

PIG IRON.

Scotland—			
Hæmatite M/Nos.	£6	13	0
Foundry No. 1	6	0	6
,, No. 3	5	18	0
N.E. Coast—			
Hæmatite No. 1	6	13	0
Foundry No. 1	5	11	6
,, No. 3	5	9	0
,, No. 4	5	8	0
Silicon Iron		—	
Forge	5	8	0
Midlands—			
N. Staffs. Forge No. 4	5	8	0
,, Foundry No. 3	5	11	0
Northants—			
Foundry No. 1	5	11	6
Forge No. 4	5	5	6
Foundry No. 3	5	8	6
Derbyshire Forge	5	10	0
,, Foundry No. 1	5	14	0
,, Foundry No. 3	5	11	0
West Coast Hæmatite	7	4	8
East ,, ,,	7	3	6

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.	
Per English ton	Kr.170
Billets, single welded, over 0·45 Carbon.	
Per metric ton	Kr.335-385
Per English ton	£17 11 3/£20 3 9
Wire Rods, over 0·45 Carbon.	
Per metric ton	Kr.375-405
Per English ton	£19 12 2/£21 4 9
Rolled Martin Iron, basis price.	
Per metric ton	Kr.230-250
Per English ton	£12 1 2/£13 2 2
Rolled charcoal iron, finished bars, basis price.	
Per metric ton	Kr.360
Per English ton	£18 17 6

f.o.b. Gothenburg.

SCRAP METAL.

Copper, Clean	£34	0	0
,, Braziery	31	0	0
,, Wire		—	
Brass	20	10	0
Gun Metal	34	0	0
Zinc	8	10	0
Aluminium Cuttings	59	0	0
Lead	14	0	0
Heavy Steel—			
S. Wales	3	10	0
Scotland	3	6	0
Cleveland	3	7	0
Cast Iron—			
Midlands	3	5	0
S. Wales	3	10	0
Cleveland	3	10	0
Steel Turnings—			
Cleveland	2	13	0
Midlands	2	5	0
Cast Iron Borings—			
Cleveland		—	
Scotland	2	2	6

SPELTER.

G.O.B. Official		—	
Hard	£9	5	0
English	14	15	0
India	14	0	0
Re-melted	11	10	0

STEEL.

Ship, Bridge, and Tank Plates.			
Scotland	£11	10	0
North-East Coast	11	10	0
Midlands	11	10	0
Boiler Plates (Land) Scotland	12	0	0
,, ,, (Marine) ,,		—	
,, ,, (Land), N.E.Coast	12	0	0
,, ,, (Marine) ,,		—	
Angles, Scotland	11	0	6
,, North-East Coast	11	0	6
,, Midlands	11	0	6
Joists	11	6	0
Heavy Rails	10	2	6
Fishplates	14	2	6
Light Rails	10	7	6
Sheffield—			
Siemens Acid Billets	11	15	0
Hard Basic .. £6 17 6 to	10	2	6
Medium Basic, £6 12 6 and	10	0	0
Soft Basic	8	15	0
Hoops	11	15	0
Manchester			
Hoops	11	5	0
Scotland, Sheets 24 B.G.	15	15	0

¶ HIGH-SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	£0	3	0
Finished Bars 18% Tungsten	,,	0	3	10
Extras:				
Round and Squares, ½ in. to ¼ in.	,,	0	0	3
Under ¼ in. to $\frac{3}{16}$ in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ⅜ in.	,,	0	0	3
,, ,, ½ in. × ¼ in.	,,	0	1	0

TIN.

Standard Cash	£215	0	0
English	215	0	0
Australian		—	
Eastern	223	0	0
Tin Plates I.C. 20 × 14 box	1	0	3

ZINC.

English Sheets	£28	15	0
Rods	16	0	0
Battery Plates		—	
Boiler Plates		—	

LEAD.

Soft Foreign	£15	2	6
English	17	5	0

* McKechnie Brothers, Ltd., Dec. 12. † C. Clifford & Sons, Ltd., Dec. 12. ‡ Murex Limited, Dec. 12.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices when about to place order.
§ Prices ex warehouse, Dec. 12. ¶ The prices fluctuate with the price of Tungsten.

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You will then be able to refer to contents of previous issues easily.

METALLURGIA. **Contents.** For DECEMBER, 1938.

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Imperial Chemical Industries, Ltd., Imperial Chemical House, London, S.W. 1.

Alloys
J. H. Clifton, London.
Electric Furnace Products Co., Ltd., Norway.

Aluminium and its Alloys
Aluminium Union, Ltd., The Adelphi, Strand, London, W.C. 2.
British Aluminium Co., Ltd., King William St., London, E.C. 4.
High Duty Alloys, Ltd., Trading Estate, Slough.
Wm. Mills, Ltd., Birmingham.
Northern Aluminium Co., Ltd., Bush House, London, W.C. 2.
Perry Barr Metal Co., Ltd., Birmingham.

Anti-Friction Metals
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Brass and Bronze
Clifford, Chas. and Son, Ltd., Birmingham.
I.C.I. Metals Ltd., Birmingham.
John Holroyd, Ltd., Rochdale.
Manganese Bronze & Brass Co., Ltd., Handford Works, Ipswich.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Casehardening Compounds
Amalgams Co., Ltd., Attercliffe Rd., Sheffield.
G.W.B. Electric Furnaces, Ltd., Belgrave House, Belgrave St., W.C. 1.
I.C.I. Cassel Cyanide.
Kasenit Ltd., Holyrood St., Bermondsey St., London, S.E. 1.

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Rudge Littley Ltd., West Bromwich.
Wallwork, H., and Co., Ltd., Roger St., Manchester.

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Magnesium Castings and Products, Ltd., Slough.
Manganese Bronze & Brass Co. Ltd., Handford Works, Ipswich.
William Mills, Limited, Grove St., Birmingham.
Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W. 1.
Northern Aluminium Co. Ltd., Bush House, Aldwych, London, W.C. 2.
Sterling Metals Ltd., Coventry.

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Honeywell Brown, Ltd., 70, St. Thomas St., London.

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Gibbon Bros., Ltd., Albert Rd., Middlesbrough.
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Crucibles
Morgan Crucible Co. Ltd., Battersea Church Rd., London, S.W. 11.

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British Acheson Electrodes, Ltd., Sheffield.

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McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Northern Aluminium Co., Ltd., London.

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McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Northern Aluminium Co., Ltd., London.

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Imperial Chemical Industries Ltd., Dept. C. 6, Imperial Chemical House, London, S.W. 1.

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Northern Aluminium Co., Ltd., London.

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Demag Electrostahl, Germany.
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Brayshaw Furnaces Ltd., Manchester.
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Gas
British Commercial Gas Association, Gas Industry House, 1, Grosvenor Place, London, S.W. 1.

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Wallwork, Henry, and Co., Ltd., Red Bank, Manchester.
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McKechnie Bros., Ltd., Rotton Park St., Birmingham.

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Shorter Process Co. Ltd., Savile St. East, Sheffield.
I.C.I. Cassel Cyanide.

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Nu-way Heating Plants, Macdonald St., Birmingham.

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Joshua Bigwood & Son, Ltd., Wolverhampton.

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Magnesium Castings, Ltd., Slough.
Sterling Metals, Ltd., Coventry.

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Metropolitan-Vickers, Ltd., Trafford Park, Manchester.

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Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness.
Bradley & Foster, Ltd., Darlaston.

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Eumuco Ltd., Beverley Works, Willow Ave., Barnes, London, S.W. 13.
Schloemann, A.-G., Düsseldorf, Germany.

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Calorizing Corporation of Great Britain, Ltd., 32, Farringdon St., London, E.C. 4.

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Alfred Herbert Ltd., Coventry.

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Cambridge Instrument Co., Ltd., London.
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Roll Manufacturers
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Lamberton and Co., Coatbridge.
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Rheinische Walzmachinenfabrik, Germany.
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August Schmitz, A.-G., Germany.
Karl., Fr. Ungerer., Germany.

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